AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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CLXXX.

(Vol. VIII.—May, 1879.)

THE CONSTRUCTION AND MAINTENANCE OF ROADS.

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Read April 16th, 1879.

The writer wishes to give the Society some statistics and suggestions regarding the construction and maintenance of wheelways, partly drawn from his experience in charge of such work and from observation and information acquired in this country, and recently in London and Paris.

EARTH ROADS.

In the construction of an earth or gravel road the effort should be to keep the material near the surface as nearly homogeneous as possible, that the surface may be uniformly hard. The upper layers at least should be thoroughly rolled in thin layers, with sprinkling, if the material is too dry to pack well. The most efficacious roller for this purpose is of two sets of disks, one about 8 inches less in diameter than the other, placed alternately on the axis of the roller. It is understood that the cost of compacting reservoir embankments with this roller is about three-fourths of a cent per cubic yard. The writer has never seen it used in road maintenance.

When the soil is sandy but little can be done besides covering it with some more tenacious material. Clay, or clay hard-pan, is the best, unless a sufficient coat of gravel can be afforded. Even a clay road, if the

traffic is not too heavy, can be kept in a firm state by careful and continuous maintenance; a coat of sand or hard-pan is, of course, desirable.

The plan often pursued of repairing roads once or twice a year is not economical, for the dilapidations increase in a heavy ratio after they commence.

A fair average for re-forming a mile of old road 30 feet wide between gutters, where the material was mostly cast from the sides, was 164 days, 10 hours each, of laborers, and two days of a double team hauling earth, carrying away stones, and moving tool-box. The use of a railroad scraper would have been an economy.

Maintenance is most economically performed by double teams, with hones or scrapers, rollers, and the watering cart in dry weather. The hone or scraper is often an oak plank, 2 inches thick, 10 inches broad, and 9 or 10 feet long, shod on its lower edge with a ¼-inch plate of iron. Drawn vertically along the road either by a tongue or a chain—in the first case it has two handles like plow-handles—in the second it has a vertical handle, and the earth is dumped by pushing it forward; a piece of plank, about 3 feet long, being fastened behind, by riding on which the driver can regulate the amount of earth moved. These are drawn over the road, inclined 7 or 10 degrees from a perpendicular, to the line of travel. So that, besides filling small depressions, they, to a slight extent, scrape the earth to or from the centre of the road. There are also some patented machines, combining a scraper and roller in a frame, which are said to be very effective. 46 000 to 47 000 square yards can be covered in a day, while not more than 2 300 can be put in order if the road is rutted and gullied. While hones are of little use on muddy roads, they are effective just as it is drying.

The ordinary type of roller has 6 rings, the whole length being 6 feet, and weighing about 2 tons; with frames that, will hold 1½ tons of stone. A better is of 2 rings, 3 feet long, also weighing 2 tons. Another is figured in Clemens Herschel's Prize Essay on Roads, and in General Gilmore's Roads, Streets and Pavements.

The roller should follow the re-forming of the road-bed, whether with hones, shovels, or the ordinary railroad scraper.

The writer has rolled earth roads with a 15 ton steam roller, but not enough to be certain as to its economic value; where the soil contained a fair amount of clay, the road-bed was left very hard, and wore well.

A water cart holding 60 cubic feet will water 830 to 860 square yards, and can be drawn by an ordinary team over any road that is worth

watering. Two sprinklings per day will keep the road in good condition, though not free from dust in hot weather or high winds, if there is much traffic on the road. Sprinkling is the only thing that will keep a road from breaking up in long continued dry weather.

The treatment of gravel roads compacted either by traffic or horse rollers, differs very little from that pursued with earth roads. When the gravel is over 1 inch in diameter, it is almost impossible to keep the road-bed from breaking up when dry, and ¾ inch would be a better size, unless continuous watering can be depended on in dry weather. Small gravel (and the same remark applies to metal for Macadam) makes a pleasanter road for travel, and can be more easily kept in order.

St. Nicholas Avenue, which will be mentioned further on, was made from nearly clean Roa Hook gravel, by the aid of a 15-ton roller, but with a horse roller it will be necessary to add clay, loam or some softer material, to any hard or clean gravel to act as binding. W. H. Grant, Member of the Society. in his valuable description of the roads of Central Park, says of Roa Hook gravel, "it being more than ordinarily clean and hard, bears an intermixture or adulteration of 20 to 25 per cent. of inferior material to perfect its binding properties." These roads have a foundation of rubble stone, not so firmly packed as Telford specified, covered with quarry chips and hard pan, which was rolled with 2-horse rollers, 6 feet long. "This is thoroughly done to prevent the gravel filling the cavities of the rubble bottom, so that its cellular character may remain unimpaired to facilitate drainage." The gravel was applied in two or three successive layers, making a depth of 4 to 6 inches. Each layer was rolled with a 2-horse roller, and the last with one weighing 6½ tons, 5 feet long, giving 217 lbs. per inch pressure. These roads, which were thoroughly underdrained and side guttered, have long been famous for their excellence ; they are pleasanter for light travel than Macadam, and are easily kept in repair, except in wet weather, when they become muddy, and when neglected, the larger pebbles make a rough road for buggy riding.

For horse rolling binding should be applied as sparingly as possible, and on the last layer, after it has been compacted, simply as a glaze to hold the stone ; if it contains clay, it should be as moist as possible, not to stick to the roller.

The so-called Tompkins Cove gravel, which is much used for entrance drives to gentlemen's places about New York, is a broken lime

stone, apparently of the cement series. It is usually spread over the road, and compacted by the wheels. The darker colored stone is very pleasant to the eye, and it readily makes a smooth wheelway singularly free from either mud or dust, even when subjected to rather heavy traffic, though it is too friable for economical use in such situations. Its performance is so different from that of the ordinary limestones that an analysis is appended:

Lime	60.20
Alumina	11.22
Silica	6.13
Magnesia	10.45
Carbonic Acid	8.00
Water	4.00
	100.00

MACADAM.

Roadways surfaced with broken stone have been in use for a long time, but Macadam, about the end of the last century, systematized their construction and maintenance, effecting such an improvement in English roads that his name seems indissolubly connected with roads of this class. His plan seems to have been essentially, to have a well drained, uniform road-bed for the reception of small, clean stone of uniform quality applied in thin courses, deprecating any addition of earth, clay, chalk, or other matter that will imbibe water and be affected by frost, under the pretense of binding it.

He held that a surface of an inch square or a stone 6 ounces in weight was of the maximum size for road metaling, anything larger than that being mischievous, and that 10 inches of solid Macadam was sufficient to carry any load, rather prefering a soft substratum, saying that the cost of maintenance on a morass was to the cost on a rocky foundation in the ratio of 5 to 7.

Telford differed from Macadam in his views, how much may be best seen from one of his specifications taken from Parnell's Treatise on Roads: London, 1833, p. 147 *et seq.*: "Upon the level bed prepared for the road materials a bottom course or layer of stones is to be set by hand in the form of a close, firm pavement. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper face is not to exceed 4 inches in any case. All of the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips firmly wedged or packed by

hand, with a light hammer. The middle 18 feet of pavement is to be coated with hard stone as nearly cubical as possible, broken to go through a 2½-inch ring, to the depth of 6 inches, 4 of these 6 inches to be first put on and worked by traffic, after which the remaining 2 inches can be put on. The work of setting the paving stones must be executed with the greatest care, and strictly according to the foregoing directions, or otherwise the stones will become loose, and in time may work up to the surface of the road. When the work is properly executed no stone can move: the whole of the materials to be covered by 1½ inches of good gravel, free from clay or earth." Of which Parnell says, "The binding which is required to be laid on, on a new-made road, is by no means of use to the road, but, on the contrary, injurious to it. This binding by sinking between the stones diminishes the absolute solidity of the surface of the road, lets in water and frost, and contributes to prevent the complete consolidation of the mass of the broken stones."

As regards the foundation, Macadam seems to have the engineers of France and England mostly on his side. In this country, it is believed Engineers generally prefer a Telford foundation. Neither Macadam or Telford used a roller, both depending on the grinding action of the wheels of wagons to compact their roads; and it was probably to lessen the brutal pulling through loose metal that Telford used his coating of gravel.

Road rolling was first brought prominently before English readers by Sir John F. Burgoyne, in a paper written in 1843 (which is reproduced by Law & Clark). And the best American practice very fully endorses his views. He recommends a weight, as the greatest attainable, of 261 pounds per inch run of roller, the use of stone dust or sharp gravel for binding and watering. His opening sentence, "the importance of rolling roads, either newly constructed or when subjected to extensive repairs, seems never to have been duly appreciated," is still true in England, for the writer saw loose stone kicking about Great George street, in front of the Institute of Civil Engineers, for over a month.

It may here be said that writers on roads have not always kept the differences between the possibilities of construction of the three types of Macadam roads (viz., traffic made, horse rolled and steam rolled) sufficiently before their readers. The grinding action of wheels will pack the hardest stones of proper size, and make a firmer road-bed than if a softer material is used for binding, but about one-third of the material is worn

out in the operation, to say nothing of the wear on horses and wagons. On account of the digging action of the horses' feet when drawing heavy rollers, horse rollers will only compact and bind the softer rocks, without the aid of binding material, and no steam roller is known heavy enough to bind trap and the harder granites, without such aid.

The only circumstance that can justify an Engineer in depending on traffic to make his road (except in the case of small, thin patches) is an inability to procure a roller; and then the material should be applied in very thin layers, for, in addition to the waste of material, the cost of raking and leveling a new road will nearly equal the cost of horse rolling, the surface will never be as good; and, as dung and dust will be ground in with the stone, it will be more affected by wet and frost. In addition, as a road is made for economy and convenience of transportation, the damage to horses and vehicles should not be allowed, even if it made a better road.

While a horse roller will make a much better road than traffic will, it is inferior to a road rolled by steam rollers, for about 260 pounds per inch run of roller seems to be the greatest weight practically attainable by horse rollers, which is not sufficient to make a road of trap and the harder stones, without the use of some softer materials as binding, which presents the objections stated by Parnell, even under the most careful system of application.

With a steam roller the weight applied can be made equal to the requirements. The horses' feet do not cut up the metal almost as fast as it is arranged and compacted by the roller. Hard binding can be used, making the roadbed nearly homogeneous and impervious to water, preventing movement of the stones on each other. Lastly, the frictional action of the driving wheels arranges and compacts the stones better than a greater rolling weight does, making, in fact, an entirely different wheelway in its wearing and sanitary aspects.

The best horse-rolled road known to the writer is the Southern Boulevard, built by Wm. E. Worthen, Member of the Society. The earth was compacted by rolling, on which 2½ inch trap was placed in one 6-inch and one 4-inch layer, when both layers were compressed as far as possible by the use of 2-horse rollers; 2½ inches of screenings were spread over and rolled in. As water was not easily attainable on the line of the road the screenings were thoroughly wet before they were carted to the road. This wheelway, which was fourteen or fifteen feet

wide, stood seven years, almost entirely without care, under a heavy carting traffic, and a good deal of light driving. But the road was never as solid as those made with steam rollers and properly puddled, opening more with the frost, and having more loose stones on it.

The writer built some horse-rolled road on an old Macadam road which was substantially worn out. The material was a syenitic gneiss, quite hard and broken by hand to pass through a 2-inch ring. It was generally laid on 6 inches thick, in one course, though where the old metal was mostly gone, two layers of stone were used. The rollers were 6 feet long, weighing about 2 tons light and 3½ loaded. They were used with 2 horses light and 4 horses heavy. The stones, which were broken on the side of the road, were handled with 10-tined forks, the tine 14 inches long, 1½ inches apart, known as "tanners' forks." These forks, with a little care on the part of the laborer, left nearly all the dust and small stone behind (the average wear of tines was one inch for 300 cubic yards handled), so that the stones went into the road fairly clean, where they were rolled; the shoulders being at the same time made up with good earth, until they were fairly compact, when the dust and small stones, left by the forks, were spread on the surface which was again covered with about ¾ of an inch of preferably clayey soil, where it was procurable, which was rolled thoroughly. If the binding was sufficiently damp, the road stood very well, showing few loose stones; but when it was too dry or the earth was washed into the body of the metal, by heavy rains, the work was not at all satisfactory.

The labor account per mile of wheelway, 14 feet wide, equal to 8 213 square yards on which 1 260 cubic yards of broken stone were placed, was as follows, the days being of 10 hours each: Spreading and forming material and loading dirt for shoulders and binding, with sweeping the old Macadam clean, but no picking, 229.5 days' labor. 24 days were occupied rolling, 13.2 with 2-horse and 10.8 with 4-horse teams.

This road, with the shoulders, was 18 feet wide and the teams travelled at the rate of 2 miles per hour; allowing 90 per cent. of the time as productive, the roller passed 144 times over the surface. The mean weight of the rollers per inch run was only 75 lbs., and the maximum 100 lbs., a weight altogether too light for either economical or thorough work.

One end of this road was on a hill, with a rise of 110 in 1 500 feet; the maximum grade being at a rate of 8 per 100. It was not judged

advisable to depend on natural moisture for the binding, and a steam pump was procured, by the aid of which the metal was made thoroughly wet before the binding was applied. The binding used on the hill was a light loam; but considering the grade, the finished wheelway was as good as when heavier loam had been used, relying on the moisture in it.

In England there does not seem to be any well-established system of road making. Some of the Borough surveyors apparently do not believe in any rolling at all; others, after carefully picking up the old road-bed, put on the stones, and after more or less traffic has passed over it, put on a 5-ton roller 5 feet long, drawn by 4 to 6 horses. The binding called "hoggin," which is a loam with coarse sand and gravel in it, is apparently not always applied in the case of repairs. Appendix No. 1 is referred to for specifications for a new road.

The repairs of the wheelway of the Victoria Embankment were made by first thoroughly picking up the old road-bed and then coating it with clean Guernsey granite, hand broken, to go through a 2½ inch ring, entirely free from dust and debris, and nearly so from small stone. Guernsey granite is about as hard as trap. It was rolled with 15 ton Aveling & Porter's rollers. When compacted, hoggin was added in sufficient quantity, and with enough water to flush the material into all the interstices and leave a surplus about the thickness of grout on the surface, which was swept with brooms in front of the rollers. The same system was employed at Russell square and Bedford place.

This did not make a good Macadam road; the hoggin acted as a lubricant, allowing the stones to work on each other under the traffic. There were loose stones on the road; five weeks after the road was completed, a kick would move the stones in front of it for fully a foot; when the surface was drying, the outlines of many of the stones could be seen by the cracks in the mud covering them; the angles of the stones were already wearing off, and after a rain, on sweeping the road, the gutters were filled with mud 4 to 6 feet wide.

It was said that dissatisfaction was felt with this system, and during the past summer an effort was made to make a road simply by rolling, without the aid of any binding. The success was no greater than that of Mr. Grant, 20 years ago, in the Central Park.

In Liverpool a mixture of broken stone and coal tar pitch is laid—one ton of pitch that will just run at 100° F., is mixed with 70 galls. of dead oil and added, hot, to 5 cubic yards of stone. The stone is *dry*,

but not heated; the mixture is rolled with a hand roller in short lengths. The surface is very good, making a favorite road for velocipede riders, and it can be swept without danger of dislodging stone, but it does not seem to have the wearing qualities of a well puddled trap road. Some laid three years in Basnat street, now requires pretty extensive repairs.

In Scotland a concrete has been used with Portland cement, for binding; the surface was very good, but when the road commenced to break, it went to pieces very fast.

M. Malo speaks of the Macadam in Paris, as follows: "Day by day, they try with incalculable efforts to perfect Macadam. They have perfected their watering in summer and sweeping in winter; they have substituted, at great cost, granite in place of limestone; they have multiplied their road laborers; each morning the devastations of the day before are repaired with incredible rapidity, but when the stream of traffic again covers the street, the scourge (*fleau*) recovers its rights, and during 300 days of the year the roadway becomes an ocean of mud or a mass of infected dust." In other words, a poor system of construction, but probably the most thorough system of maintenance to be found anywhere. A. Debauve, in his "Manuel de L'Ingénieur," after speaking of the immense capital invested in the old Roman roads, says: "The tendency now is to have the thickness only that which is necessary for resistance, to suppress the foundation, and, in one word, to economically establish the roadways and maintain them afterwards in a fit state by incessant repairs which the ancients did not know of."

In Paris the Macadam roads are composed of water-worn flint pebbles which are compacted by ramming with a rammer 8 inches in diameter, weighing 70 lbs., and horse rolling with the aid of sand and water, *meulière*—a kind of burr mill stone—and porphyry, the two latter are generally steam rolled. These materials are used, according to Debauve, in the following proportions, viz., flint, 10 per cent.; meuliére, 67 per cent., and porphyry, 23 per cent.

Macadam roads in Paris as in London, are the roads of luxury. On many streets, the centre, for a width of 19 feet, is covered with Macadam, while the sides, for a width of 13 feet each, are paved with stone sets or asphalte. The Avenue des Champs Elyssés, Place Concorde, and some of the Quais are of flint; other of the Quais and Rue de Rivoli are of harder stone, while the Avenue de l'Opera, Boulevard Haussmann, etc., have Macadam only in the middle.

The French, who use the Gellerat roller in Paris, specify a maximum weight of 448 lbs. per inch run and a maximum speed of 2.3 miles per hour. The rolling is done by contract (the city furnishing water) at a rate per ton mile varying from 15.26 to 7.63 cents according to the amount, with an increase of $\frac{1}{3}$ in price where the grade exceeds 6 per cent.

The thickness of metal rolled varies from 12 inches on new roads to 2 inches on old. It is maintained that the work of compacting a cubic yard of the same stone is independent of the thickness when that varies between 2 and 6 inches and is from 2.7 to 3.27 ton miles per cubic yard.

From a table (p. 308) in the notice of the objects, &c., exhibited by the City of Paris at the Exhibition of 1878, it is seen that the mean weight per inch run of the steam rollers is 448 and 336 lbs. and for the horse rollers 263 lbs. Also that the ton miles necessary to make a square yard of porphyry wheelway, or to compact a cubic yard of the same metal, are as follows: the mean for the two models of machines weighing 448 lbs. per inch run was, per square yard, with thickness of 3.9 inches, 0.41 ton miles, while for the roller of 336 lbs., with a thickness of 2.8 inches, 0.234 ton miles were required, or 3.78 and 2.99 ton miles per cubic yard respectively, and for horse rollers where the thickness was 2.6 inches, the ton miles required were 0.194 per square yard and 2.69 per cubic yard. The amounts consolidated per ton per hour are in the following proportions: 467 for the heavy rollers, 539 for the light roller, and 297 for the horse roller, and the number of passages of the rollers were 98.5, 75 and 92.

It appears from these tables that the smaller weight is the more advantageous, and that horse rolling is cheaper than steam rolling; it is added, that, on account of their superior celerity, the steam rollers are almost exclusively employed.

No statement is made as to the relative wear of stone rolled by the different machines.

About 24 per cent. of sand is used for binding. The surface is allowed to wear down until 2 to 6 inches of metal is put on.

Repairs were being made on Boulevard Haussmann by a 5-inch layer of *meulière*, very nicely hand broken to pass through a 2½-inch ring, free from dirt and small stone; the roller had a weight of 360 lbs. per inch. After a few passages had been made over the stone, very clean sand was spread on, which was shortly wet by a hand hose. The water was not at

first applied in sufficient quantity to flush the sand thoroughly into the interstices, but the sand was just damp enough to pick up the stones. The speed of the roller was thought to be fully 2¼ miles per hour. The binding was not so thoroughly wet as on the Victoria Embankment, nor was the metal rolled as much. When the street was thrown open to traffic the consolidation was about at the point at which in this country we would commence applying screenings, stones were picked up by the wheels, and a light kick would move the stones for from 1 to 1½ feet in front of it.

On the Avenue de l'Opera, the centre of which is covered with broken porphyry, the stones presented the same evidences of motion on each other, mentioned as seen on the Victoria Embankment.

In New York City there are, including St. Nicholas avenue, 27.99 miles or 921 400 square yards of steam rolled Macadam roads, besides the horse rolled roads in the Central Park and the Twenty-third and Twenty-fourth Wards, of which 17.75 miles or 718 200 square yards are on Telford foundations. They were commenced in 1869, and mostly finished in 1876.

The first had a 5-inch layer of gneiss laid on the Telford, on that a 5-inch course of trap, both broken to go through a 2½-inch ring. The trap was and is machine broken, and the screenings, *i. e*,, dust and stone that passes through a 1-inch or 1¼-inch aperture, are used for binding. At first it was held that these should be used as sparingly as possible, but experience has shown that the roads wear better and have less loose stones on them when the interstices are fully filled with screenings, and the size of the stone in the top course is preferably from 1 to 1½ inches. The general practice now is to put on the stones in two courses when the thickness, compacted, is 6 inches or more, and roll the first course until it will settle no more, then add the last course, and after it has settled, screenings are added, at first coarse and then fine, and after thorough rolling, the whole is puddled by a copious addition of water. This is accomplished more thoroughly and satisfactorily in hot, dry weather. After the road is puddled ¼ to ½ inch of screenings are spread over it, and after drying an hour or so the traffic is turned on.

For the old style of construction Sixth avenue, between One Hundred and Tenth street and Harlem River, may be taken as a type, having the materials and courses as above mentioned. It was rolled with

Aveling & Porter's 15 ton rollers, of the old pattern, in which the weight is nearly equally divided between the steering and driving wheels, which cover 6 feet, giving a bearing weight of 467 lbs. per inch run. As near as can be ascertained, $24\frac{6}{10}$ hours, at $1\frac{1}{2}$ miles per hour were occupied in rolling 1 000 square yards, giving for the work done 0.553 ton miles per square yard, 2 246 ton miles per cubic yard, and 129.8 trips of the roller over the surface.

Avenue St. Nicholas, which, as mentioned above, was made from Roa Hook gravel, had a rubble foundation, and it was intended to have 6 inches of compact gravel, but the foundation settled so that in some instances the gravel is 14 inches thick. The practice was to lay the gravel on and wet it thoroughly over night. It was rolled the next day until the water was forced to the surface. A 15-ton roller was employed about 26 hours per 1 000 square yards, besides some horse rolling. A little hard pan was used for binding. The intention was to make a road for fast driving, but the surface was as hard as that of a Macadam road, though much smoother.

The data for these two avenues depend on the memory of the engineer of the roller, and are approximate only.

The Telford Macadam on Fifth avenue has 8 inches of Telford, 3 inches of $2\frac{1}{2}$-inch trap, 4 inches of 2-inch trap, 1 inch of coarse screenings, and one-half inch of fine screenings, when completed. The wheelway is 40 feet wide between curbs, with 4 feet gutters on each side, of trap blocks. (For Specification see App. 2 and Plate No. XXIV.)

Mr. F. H. Hamlin, for some time Engineer in the charge of Roads and Streets in New York City, to whom I am indebted for these data, intended, by the use of the $1\frac{1}{2}$ inches of screenings, to have the road as smooth and pleasant for riding as Avenue St. Nicholas, without the tendency to mud in wet weather. The work was let in two contracts, at $1.30 and $1.49 per square yard. The average time employed setting a square yard of Telford was $20\frac{1}{2}$ minutes. Spreading the stone and screenings, per square yard, $1\frac{2}{10}$ minutes. About $58\frac{6}{10}$ hours rolling were given per 1 000 square yards; and the work done, allowing the effective speed to have been $1\frac{1}{4}$ miles per hour, was 1.099 ton miles per square yard, and 4.709 ton miles per cubic yard of compacted material, if there had been no settlement, but there was an unascertained settlement.

These roads are maintained by spreading very thin layers of fine Roa Hook gravel over them and watering. The first roads were built with

an idea that as small a quantity of screenings as possible should be used, and in dry weather, the stones which become prominent by wear, are liable to kick out; the fine gravel prevents this, and by retaining water, sprinkling is not necessary so often. The fact that the travel concentrated near the gutters, where this gravel, by the action of rain, becomes thickest, in connection with the demands of owners of fast horses, who wished a softer road-bed, led Mr. Hamlin to cover one of them with a coating three-eighths of an inch thick, consisting of three parts of coarse sand and one part of strong clay. This has been on the road through two winters, and the road-bed is still firm, and it has been applied to others.

Under Mr. Hamlin's charge the average cost of maintaining these roads has been $4\frac{3}{10}$ cents per square yard per annum for the labor and material of road covering, cleaning and sprinkling, with incidental repairs and supervision. None of them have been resurfaced with broken stone, excepting a portion of the Western Boulevard, the first built, and two or three patches of 100 feet or less in length, which cost 46 cents per square yard.

It is very difficult to estimate the traffic on these roads. On a fine day 3 000 vehicles may pass over them, while at other times there may be not more than one-tenth of that number.

In repairing the Southern Boulevard, mentioned above, the trap broken to go through a 2-inch ring, was laid on 6 inches thick in one course; $38\frac{3}{10}$ hours rolling was given per 1 000 square yards. Allowing the speed to have been $1\frac{1}{2}$ miles per hour, the work done on it amounted to 0.859 ton miles per square yard and 5.177 ton miles per cubic yard; 201 trips were made over the surface. The Macadam was 15 feet wide, and some of the rolling was on the shoulders, though probably not enough to affect the result materially. The work was done in July and August, and a little less than 0.6 cubic feet of water per square yard, (3.5 cubic feet per cubic yard) were used in compacting and puddling. About one-third screenings were added. Those portions of the road that had the most work done on them are now in the best form, after nearly two years without any care; and generally the more thoroughly the trap roads were rolled the better do they wear.

It should be understood that there was no counter on the wheels of the rollers, and the speed is the result of estimation, interfering with accuracy in the estimate of the number of ton miles performed. The

rollers used in the above mentioned works were 15-ton Aveling & Porter's (old pattern), and though they are understood to bear equally on the driving and steering wheels, the writer thought the driving wheels nearly twice as effective as the steering wheels.

The superiority of the American Macadam roads is partly due to the greater amount of work put upon them; the bind g, which is of the same hard material as the metaling, almost completely fills the interstices between the stones and the entire mass is thoroughly compacted and nearly homogeneous. It is only while the frost is coming out of the road in the spring that the stones wear upon one another at all. The process of puddling gives a very smooth, hard firm surface, resistant alike to wear and the infiltration of water, which is of equal advantage to the stability of the foundation and from a sanitary point of view. By the use of the steam roller the stones are compacted with a small amount of wear to their angles and an entire freedom from mud and dung, their only weak point being that in long-continued dry weather the larger stones are apt to get dislodged from the surface, some moisture being necessary for the full cohesion of the binding. No amount of wet weather, unaccompanied by frost, seems to injure them, unless mud works up through the foundation, and their imperviousness under the most disadvantageous circumstances is well illustrated by the practice of Mr. Hamlin, as cited above.

The English roads are rolled less, and the binding, though cheaper in cost and in the matter of rolling and spreading, is, when thoroughly wet, to a great extent an element of weakness to the roads, allowing a large part of the wear to be internal, and failing to hold the stones from dislodgment, either by the wheels of vehicles or the brooms of the sweepers. When dry it can have neither cohesion nor resistance, its use being confined to the time it is slightly damp.

The roads in Paris seemed to be less thoroughly compacted than in London, but the binding was better, and if it had been applied dry, after the stone was nearly compacted, and only wet at the last rolling, it would probably be more effective. As it was, the grain of the sand seemed to have been broken down during the rolling of the stone, and as, like the English made roads, the stones move on one another, it must be still more thoroughly ground up.

The maintenance of roads in Paris is much more effective than in London. It consists essentially in washing rather than sprinkling them,

and sweeping the mud and debris of the surface into the gutters, where it is washed with a copious flow of water, the mud and fine sand going into the sewers, the coarser sand being retained for use on the streets. Most of the work is done at night and in the early hours of the morning. While there is on the average (judging from the amount of mud relative to the traffic) rather more wear than in London, no loose stones were seen on the streets, except when newly mended, men apparently being always present with brooms, rammers, and sand, to repair any place that showed signs of weakness. On the Avenue des Champ Elysées, and other flint roads, the surface was often swept with birch brooms having long and slender twigs.

In London the maintenance is neither so constant or skillful; the roads are watered in dry weather, and swept or scraped in wet, with an occasional addition of sand or fine gravel.

There seems to be no accessible accounts of the cost of repairs and maintenance in London. W. S. Till, the Borough Surveyor of Birmingham, in one of his reports, says: "Mr. Howell, Surveyor to the Vestry of St. James, Westminster, informs me that the cost of maintaining, &c., the surface of Regent Street, London, which may be considered one of the best Macadamized roads in the Kingdom, and in which nearly every description of pavement has been tried, is $0.87 per square yard per annum; it has, however, been much higher." It is not known whether Regent Street was then steam or horse rolled.

In Paris, the expense of maintenance had reached on some of the streets 16 francs per square meter ($2.57 per square yard) per annum, and it was resolved to pave all but the middle 23 feet, in streets 48 feet wide, and to pave narrow streets and gutters, and in 1871 it was resolved to pave streets where the annual expense of maintenance was over 48 cents per square yard, excepting those avenues which are used by carriages of luxury. This, however, was not fully carried out.

Many adverse criticisms are made on Macadam roads by parties who judge of their value mainly from reading statements regarding European Macadam. A well made trap road, when properly watered and maintained, is, after an earth road, the pleasantest and safest road known. In this locality a road 15 feet wide would give suburban residents the same easy access to their railroad stations in the worst winter weather as in summer. And for streets of residence, where the inhabitants would keep them free from garbage, both for quiet, safety to horses, and on sanitary grounds, they are preferable to the ordinary paving.

It is possible that with thoroughly compacted and bound roads, the English and French Engineers would look with more favor on Telford foundations, for with the roads we make, the wear between the Macadam and Telford must be very slight, the pressure of a wheel being spread over a large surface. They are preferred here because they give an equal depth of foundation more cheaply than with broken stone, and as in this country municipal appointments of Engineers are sometimes influenced by political considerations, the general desire is to build as solidly as possible.

One objection that may be urged against the Telford foundation is the fact that it does not have a solid bearing on the earth roadbed, and when the road is worn thin the spaces between the stones may become filled with water and mud, which will work through the foundation into the broken stone, hurrying the disintegration of the road.

The English Engineers often use "hard core," a mixture of brick rubbish, old plastering and broken stone, on a clay soil, to prevent the mud working into the metaling.

This result was accomplished by the use of six to eight inches of fine sand on Mott avenue, New York, which was built at the joint expense of the City and private parties. The regulation of the surface required a maximum cut of two and a half feet and a fill of four feet; the soil was a heavy loam, thoroughly saturated by the fall rains, which continued until the work was completed, and it was desirable to Macadamize it immediately. Rough gneiss rock was placed on the layer of sand and rolled to an even surface, with a thickness of about eight inches, and on that a scant six inches of loose 2-inch trap, to which thirty per cent. of screenings were added. The bottom was very treacherous; on about half the road it was not safe to stop the roller, which broke through in two instances in spite of the care exercised. Nor could the road be rolled long in one place; but as soon as the surface began to weave in front of the roller it was given a rest, and the roller taken to another part of the road. In spite of this the road was compacted and the surface puddled satisfactorily, except in one or two small patches. It has stood the freezing and thawing of two winters without receiving or requiring any attention.

It is held that the success of this operation, so contrary to the teachings of the books, was due to the layer of fine sand being impervious to the mud, which without it would have been over the top of the Macadam a long time before it was puddled.

The deductions of the French Engineers from the table cited on page 12 should have been strengthened or modified by a statement of the wear of the different work done. And their principles of road construction are dissented from, because the writer believes that the horse roller made road does not differ so much (after both are compacted) in wearing value from the road specified by Macadam as it does from the road properly made by a steam roller; that all binding should be fully as hard as the stone, and that the better road is made with the heavier roller per inch run, as far as his experience has gone, *i. e.*, up to 460 pounds. And, in addition, that up to that weight the ton miles rather than the load should be altered on account of the greater or less hardness of the rock employed for road construction.

It is believed that no one who has used the two styles of 2 ton rollers mentioned, viz., 3 feet and 6 feet long, doubts that the 3 feet roller will do better work than can be accomplished by the 6 feet roller without loading.

Under the writer's direction the same quality of syenitic gneiss mentioned on page 9 was rolled with a 15 ton steam roller, with binding of the same quality in both cases. There were only about 200 cubic yards of it, and on account of the traffic passing, it was impossible to keep an exact account of the work done, but the road is very satisfactory, and from it the writer thinks that a few passages of the steam roller over the horse rolled road would add materially to its life, besides greatly reducing the number of loose stones on its surface.

Some refuse Westchester marble (a very soft rock) was delivered on some of the roads at about 25 cents per cubic yard, and hand broken in place at the rate of about 1 cubic yard per hour. A portion was rolled before any traffic went over it, some after about two weeks of traffic and some after six weeks; of the rest, part was horse rolled and part compacted by wheels; the quality of the stone, traffic, etc., were very nearly the same; that not rolled by the steam roller soon wore into holes, the first mentioned is, after standing two winters, in very fair surface; the others decreasing in the order in which they are mentioned. This difference is so noticable that anyone could pick out their sequence as mentioned.

Shortly before this, however, the writer very nearly made a mush of some micacious gneiss in trying to reduce the crown of a road covered with it.

Late in the fall a portion of the Southern Boulevard was repaired with 2 inch trap, screenings, and a 2 ton horse roller. After the metal was compacted a thin coat of clay hard pan was added, which froze solidly that night, and a day or two after was covered with snow which staid on till spring, thus giving it the most favorable surroundings possible. In the summer there was but little difference between it and the steam rolled part; but by fall it had commenced to deteriorate, and now its surface is but little better than that made seven years before.

Both the English and French prefer hand-broken stones for Macadam. An experienced breaker will make better shaped stones than any crusher can, and hand breaking would afford employment to labor. The hand broken stones mentioned above were delivered by contractors at $2.00 per cubic yard; the men who broke receiving on an average 82½ cents per yard. One man was thought to have broken at the rate of 4.5 cubic yards per day; about 6 to average 2½ yards or more. They stood, using hammers weighing 1¾ to 2 pounds, on very flexible handles. The average of all who worked could not have been much over 1 yard per day.

On the other hand, there is not enough fine stone for binding, what there is, is full of dirt, and machine breaking is cheaper; the cost of crushing trap with a Blake crusher, after it is sledged, being understood to be less than 70 cents.

The crown or transverse section of a road should depend on so many different considerations that no general rule can be drawn for it. With Macadam made from hard material, the less crown, on many accounts, the better, as the surface is benefited by being kept damp. In narrow wheelways, particularly, an excessive crown throws all the traffic, as much as possible, in one line, whatever the material may be. On the other hand, in curbed streets, if the road is too flat, the heavy traffic tends to concentrate near the gutters. The crowns given to dirt roads are intended to drain off the water, but the longitudinal ruts soon defeat that object.

Transverse profiles of the Western Boulevard and Sixth avenue, New York City, are shown (Plate XXV). On the former, though the transverse slope is so slight, it is perceptible to a person riding in a vehicle with longitudinal seats, but is not noticeable when on a transverse seat. The cross section of Sixth avenue shows the surface as the road was constructed by M. A. Kellogg, Engineer, in 1872 and 1873, with the

crown at the same height as the top of the curb stones, and the figures above the dotted line joining the curbs show the average distance of the surface below street line, as found by careful levels taken this spring between 123d and 124th streets, a point where no broken stone had been added, the wear at the crown being 0.15 foot, or about ½ inch per year. The road is not too flat, as it now stands, to shed the rain fall.

The amount of water the writer found necessary to keep earth or Macadam roads from becoming dusty, was, for a well maintained earth road, at the rate of 71.3 cubic feet per 1 000 square yards, applied twice a day, or say 143 cubic feet per day. In very hot or breezy weather this was not quite enough.

On the Telford roads of this city, 25 cubic feet, applied four times a day, are necessary per 1 000 square yards, say 100 cubic feet per day. One water cart, holding 79 cubic feet, waters 35 000 square yards four times a day, keeping it free from dust, except during windy weather.

In Paris about 27 per cent. of the surface is watered by hand hose. These are made of iron pipes about 6½ feet long, each end supported on castors and connected with leather or rubber couplings; the working end being a piece of rubber hose. Its cost is one-half that of watering by carts holding 46 cubic feet.

Stone Pavements.

The City of New York is largely paved with the Belgian pavement, *i. e.*, truncated pyramids of trap set in coarse sand. The sand soon becomes saturated with the water and mud of the streets, and the blocks working under the traffic become rounded. It is impossible to keep such pavements in fair surface, and they are about as bad sanitarily as pavements can be.

The pavements now laid are of granite or trap blocks, 4 inches wide, 6 inches deep, and 8 to 12 inches long. They have parallel sides, and are laid in sand, probably forming the most efficient pavement for the cost ($1.91 per square yard), to be found anywhere. The open joints filled only with sand are objectionable, however, as forming receptacles for street mud and water.

The Guidet pavement laid in Broadway, with a foundation of concrete, has lasted very well, its increased wear probably compensating for the additional cost of the concrete foundation.

In Paris, the new pavements are of Gris, a hard sandstone, which is neatly dressed in blocks, 4 to 5 inches square, and laid either in

sand or mortar, and porphyry, about 4 inches wide, 6 inches deep, and 8 inches long, generally laid in mortar.

The best granite pavements are found in England. In London, where the soil is clay, the usual practice is to lay a foundation course of "hard core" which is well compacted by rolling, &c., and the stones are set on this in 2 inches of sand. The better class of pavements, on clay, have 3 to 6 inches of hard core, 9 inches of concrete, and 2 inches of sand. Col. Haywood, where soil is sand or gravel, puts down 9 to 18 inches of broken stone, or 9 inches of concrete, saying that there is little difference in the stability of the two foundations, but the concrete is apt to be replaced in a more satisfactory condition when the street has been opened.

In all the better class of London pavements, the sets are 3 inches wide, neatly split out with parallel sides, and set in blue lias lime grout; Aberdeen granite being chosen in preference to harder varieties, as it wears rough. Though Col. Haywood determined that the duration of the same stone varied directly with their size, these narrow sets are preferred, as making a smoother road, affording a better foothold for horses, and increasing the quietness and general comfort. The practice is to take up the sets when their surfaces become rounded, and redress them, after which they are relaid in streets of secondary traffic. The spalls are useful for foundations and Macadam. Col. Haywood estimates the total life of such paving stones to be 29 years.

In Liverpool, Geo. F. Deacon prefers the Welch traps and granites which are rather harder than our trap. The pavement of North John Street, which has a traffic of 4 000 vehicles, averaging 3 tons each, per day, is of trap blocks, neatly split out, with parallel sides, 6 inches deep and 3¼ x 3¼ inches on the face, set on 10 inches of concrete, the joints are filled with gravel, about the size of a pea, free from sand, and then run with coal tar pitch. It had been paved very close, and the sets were so firmly held in place, that there was hardly any rounding of the surface last winter, though it was laid in 1872. The surface was admirable, and showed very slight wear, and on sanitary grounds, it is probably unequalled by any other pavement, except compressed asphalte, for there can be no percolation of the surface water. The only signs of failure shown by this pavement, is where the boiler of the "Montana," weighing with its 4-wheeled truck 59 tons, passed over it, crushing some of the sets, and showing that stones 3¼ inches square on the face, are not large enough to stand loads of 15 tons per wheel.

Mr. Deacon thinks that the 3½ inch square blocks present too many longitudinal joints and now employs sets 3 inches thick by 6½ inches deep, and 5 to 7 inches long; the specification for thickness is that any 4 of them, when set side by side, shall measure 12 inches, and not more than 14 inches. It is said the specification is filled without extra cost.

Wood Pavements.

In London, the principal wood pavements are Cary's, the Improved Wood, Henson's, and the Asphaltic Wood. Cary's is laid on sand or gravel, a firm foundation being first made. The patent is for dovetailing the blocks on their ends, which is held by the inventor to give the pavement greater stability. The joints are flushed with blue lias lime grout. The advantage claimed for this pavement is the ease with which it can be repaired, the method being apparently to take out the defective block or blocks, cut off the broomed portion that overhangs the sides of the blocks, put in enough gravel to restore the surface, replace the block with the other face up, and run in the grout. A portion of Cannon street is laid with this pavement. It is said by persons on the street to require frequent repairs. Its power of resisting wear must depend on its foundation, and it can hardly prevent water from working into and through the foundation.

The "Improved Wood" Company started to make an improvement on the Nicholson patent, using two tarred boards, resting on sand, under the blocks. Ludgate Hill, and some other streets, were laid on this principle, but, under the heavy traffic, the two boards acted like a pump, pumping the sand up through the pavement. After trying and discarding one board laid on concrete, they now lay a foundation of concrete 6 inches thick, on which the blocks are placed; the joints are filled with pitch and gravel. This modification apparently makes a good pavement, as seen on Ludgate Hill, where the first pavement has been renewed, and at St. Paul's Church-yard. No company now lays boards as a part of its foundation.

Under the name of Ligneo Mineral Pavement, a company laid some pavement of hard wood, but it proved so slippery that work under that patent has been mostly abandoned. The most work seems to be done, at present, by the Henson and Asphaltic Wood Companies.

In the Henson pavement the 6 inches of concrete is covered with a layer of tarred felt paper, on which the blocks rest, while a strip of the

same material is placed vertically between each row of blocks across the street. Nothing is interposed between the ends of the blocks. After each few courses are laid the blocks are driven close together by a heavy maul. Hot coal tar and pitch is plentifully applied to the upper surface, after which gravel is strewn over it. It will be observed that this pavement presents about as small a joint for foothold as is possible, and to meet objections on this score, at first about every fifth course had a V-shaped groove cut in its top. This has been abandoned by the company, who now lay the surface flush, making a road almost free from noise and nearly as smooth as a compressed asphalte pavement. In answer to objections to their narrow joints, their Engineer asserted that they had changed the practice of the other companies in London from 1¼ or 1 inch joints to as near a quarter of an inch as it is practicable to make them, to the decided advantage of all pavements. They also assert that the tarred felt under the blocks will not wear out, that the pavement is impermeable to water, and that it can be more thoroughly cleaned than any other wood pavement. This pavement was taken up, for pipe connections, in Leadenhall Street and High Holborn. Although it had been raining in the first instance, and raining and freezing in the other, the wood was bright and not at all water soaked; the felt underneath, however, was considerably worn. The claim in regard to cleaning is probably correct.

The asphaltic wood pavement, laid under the patent of H. S. Copland, C. E., has on the 6 inches of concrete a quarter of an inch of tempered Trinidad bitumen, on which the blocks are placed; the joints across the street, which are kept between a quarter and an eighth of an inch, are run with a softer bitumen for about 2 inches, and flushed with lias lime grout, the ends of the blocks abutting against each other; the whole is covered with gravel. The pavement, unless cracked by the settlement of the foundation, must be as impervious to water as one of asphalte, and should stand the traffic very well. On account of its rigid foundation it is more noisy than the Henson, and having a slightly wider transverse joint, it hardly rides as smoothly after some wear, though the difference would not be readily noticed. It should be noticed that the bitumen which is run in the joints makes a firm bond with the layer under the blocks, and more wood is spoiled in taking up this pavement than any other observed.

This pavement was first laid in Cannon Street, between Abchurch and Laurence Pountney Lanes, in July, 1874. It was laid, apparently,

with joints rather over than under 1 inch, and in December, 1878, the edges of each block had broomed over into the joint; otherwise the surface was good, and I could not learn from any source that repairs had been made on it, except when the street had been opened for pipes. The grade is 1 in 90; and in 1873 the number of horses passing over it in 12 hours—from 8 A. M. to 8 P. M.—was 5 350.

The practice in London is to cover the surface of wood pavements several times a year with hard gravel, which is beaten into the ends of the fibres by the traffic, tending to preserve the blocks from wear, and it is claimed, from decay. The wood used is a species of pine—Baltic fir—harder than our white pine and softer than Southern or pitch pine, resembling what is sold in the Chicago markets as Norway pine; it is better seasoned than the pine generally used by house carpenters in this country, and is usually laid without being creosoted, the borough surveyors claiming that the difficulties of inspection are increased by creosoting; but as far as noticed, for renewals and repairs which are made by the companies under their contracts for maintenance, creosoted wood is used; their managers saying that they expect it to add to the wearing qualities of the wood as well as to protect it from decay. The concrete, usually covered with a thin coat of cement mortar, is made of one part of Portland cement to 6 parts of Thames ballast, which varies in size, from sand to pebbles three-quarters of an inch in diameter.

It is rather difficult to arrive at the durability of either wood or asphalte pavements in London, as Col. Haywood, the City Engineer, lets them at a certain price with a provision that they shall be kept in repair for a term of years at a certain price per square yard per annum, a good pavement being turned over to the City at the expiration of the contract for maintenance; the contractor in the meantime replacing the entire roadway, if necessary, as will be noticed under the head of asphalte. This plan has worked so well in the City that the surveyors for the vestries have generally adopted it, so that in London, the wood paving contracts are usually let with the same length of maintenance as for compressed asphalte, and at about the same price, viz.: at a first cost of from $4.38 to $3.90 per square yard, including foundation, but not excavation. They are kept in repair for two years at the contractor's cost, and at the rate, depending on the amount of traffic, of from 36½ to 18¼ cents per square yard per annum for the succeeding 15 years.

From the report of Col. Haywood to the Commissioners of Sewers of the City of London upon asphalte and wood pavements, 1874, page 38, *et seq.*, we find that the greatest duration of any wood pavement was in Mincing Lane, nineteen years and one month; the average cost per square yard per annum having been, in that instance, thirty-five and one-half cents, while the average cost of three heavy traffic streets had been sixty-three and nine-tenths cents. He concludes that, with necessary repairs, wood pavements will last ten years in London.

Law & Clark's Roads and Streets, page 239, gives the wear of three wood pavements at three-tenths of an inch per annum under a traffic averaging 362 vehicles per day of twelve hours for each foot in width of the street. Mr. Clark says it is claimed, in some instances, blocks have worn down in London to a depth of two and one-half inches (the Wells street pavement was only two inches thick, before removal), and suggests eight or nine inches as a better depth than six inches, now universal. The blocks of the Mincing Lane pavement, which lasted nineteen years, were nine inches deep. If we assume that the blocks are six inches deep, and that the road will not break up until they have worn down three inches, there seems no reason why a thoroughly creosoted wood pavement, laid with narrow joints, on a sufficient bed of concrete, with a water-tight stratum interposed, should not wear for about ten years in our streets of heaviest traffic, with a small amount of intelligent maintenance.

There have been several charges made against wood pavements, which are mentioned here, not as a matter of information, viz., that they soon become full of holes, are impossible to clean, are difficult to replace when the street is opened, and that by their rotting the health of the community is endangered, to which may be added that for only a short time do they present any barrier to the saturation of the soil by surface water.

The general practice, as far as observed by the writer, in this country has been to lay *green* or wet pine blocks, more or less thoroughly dipped in coal tar, on a bed of sand, not always thoroughly rammed, with or without the interposition of a tarred pine board, with transverse joints from one to one and one-half inches wide filled with gravel and coal tar, which was theoretically thoroughly compacted. Omitting those which, without the slight pretense of a 1-inch board for foundation, speedily became a wood Macadam, the first failure was from the blocks rotting on the bottom in patches, so that the surface would first be found to be *sheared* down by a heavy load; and on taking out

the blocks they would be found sound on their tops, where the gravel had been driven into them by the traffic, and also a sound film of about the thickness that tar could be expected to penetrate a wet block, the inside being rotten. In other cases, however, when the layer of sand was too thin, the mud worked up through both boards and blocks, reducing everything to about the state of those having no boards under them.

A layer of concrete, covered with Trinidad bitumen, will effectually stop the mud from coming up, and any percolation of the surface water into the soil through the pavement; the narrow joints, by preventing the edges of the blocks burring over, will both tend to keep the surface smooth, lessening the shocks of the wheels, and greatly facilitate all the operations of cleansing. Creosoting, by the preservative and antiseptic properties of the dead oils used in that process, will probably keep the timber from decay, so that nothing but abrasion need be feared, and the sanitary objections to decaying wood will be removed.

The following note of some experiments by E. R. ANDREWS (published in "Engineering News") shows the efficacy of creosoting for protecting wood from moisture.

The following are the results of some careful experiments with different varieties of wood, half of the specimens being simply dried and the others creosoted, to ascertain to what extent wood is rendered water-proof by creosoting. The specimens were soaked during two days in water, being carefully weighed before and after soaking:

Varieties of Wood.	Percentage of Water absorbed.
Spruce, creosoted	.0236
" "	.0306
" dried only	.1754
" "	.3333
" Burnettized	.2500
Hard pine, creosoted	.0000
" dried only	.1600
Oak, creosoted	.0625
" dried only	.2000
White birch, creosoted	.1240
" dried only	.4300
Cottonwood, creosoted	.3470
" dried only	.7140
Black gum, creosoted	.1250
" dried only	1.0000
Sesquoia Gigantea (great tree of California), creosoted	.0000
" " " dried only	.4722

In the rooms of this Society are creosoted fir ties from England that have been in the track for 20 years, and apparently justify the assertion of the Engineer sending them, that they are good for 10 years more.

The following extract, from the "Railroad Gazette," is also corroborative:

The German Railroad Union, some time ago made inquiries as to the extent to which processes for preserving ties were employed, and what the results were.

It appears from statistics of German railroads which have used treated ties more or less since 1840, and therefore have had time to test thoroughly the life of the ties, that the average life of ties not treated, and of those treated with chloride of zinc or creosote has been:

	Not treated.	Treated.
Oak ties	13.6 years	19.5 years
Fir ties	7.2 "	14 to 16 "
Pine ties	5.0 "	8 to 10 "
Beach ties	3.0 "	15 to 18 "

The average life of 831,341 pine ties treated in various ways on thirteen German roads was 14 years.

It follows from this that there is an increase in the life of ties treated with chloride of zinc or creosote, amounting to about 40 per cent. for oak, 100 to 130 per cent. for fir, 60 to 100 per cent. for pine, and 400 to 500 per cent. for beech.

It thus appears that there is a great deal gained with any kind of wood, but most with some of those usually not considered good for ties, fir and beech being made almost as durable as oak. Bischoff says that it is of little advantage to secure the ties from decay for longer periods than above stated, as the ties usually become worn out or crushed by that time, even if not decayed.

Commenting on these facts, Bischoff, says that it is now generally admitted that the choice lies between creosote and chloride of zinc; that creosote is the best antiseptic material, but also that it is the dearest.

There can be but little doubt that the antiseptic properties of the creosoting process are of more value than the increased life it would give to the blocks.

On account of the absence of proper stone and the cheapness of wood in large areas of our country, the small first cost of wood pavements seems to make it worth while to give them an intelligent trial.

The thoroughness with which wood pavements can be cleansed depends on the size of the joints and the firmness of their filling. The practice in London, when the mud is at all sticky and not so thick as to require scraping, is to water and then sweep with a revolving broom, the thoroughness of the cleansing being almost directly as the amount of water. In hot weather a disinfectant is sometimes applied after sweeping.

Asphalte and Bitumen.

Dictionary and encyclopedia makers, as well as chemists, seem to use these terms interchangeably. M. Leon Malo, in his "*Guide Pratique pour La Fabrication et L'Application de L'Asphalte et des Bitumes*," after speaking of the lack of definition in the two terms as generally used, gives the following, viz. :

"*Asphalte*, Bituminous Limestone."

"*Bitumen*, The black and viscid substance which we find disseminated in the pores of bituminous limestone and in the interstices of the molasses of Seyssel or the sands of Auvergne."

"*Asphaltic Mastic*, Bituminous limestone transformed by dressing (*cuisson*) and by the addition of a small quantity of bitumen."

He adds: "We employ these definitions throughout this work, and give to them the senses which we have just indicated, and I hope strongly that they will be adopted for use, for they seem to be the most reasonable."

It is believed his definitions have been generally accepted by European technical writers and in specifications relating to the use of these materials,* and the writer in this paper will use them as above defined, excepting that the bitumens from Trinidad and Cuba will be included with those mentioned by M. Malo.

In view of the practice in this country two other definitions seem necessary, viz.:

Bituminous mastics, mixtures of bitumen, either having an earthy *gangue*, like those of Trinidad and Cuba, or purer ones, like Grahamite and Albertite, with limestone or other substances not naturally impregnated, which add to its resistance to wear, and—

Tar Mastic, a mixture in which the bitumen is replaced by (usually) gas tar.

M. Malo further characterizes asphalte as a carbonate of lime perfectly pure (excepting, sometimes, a trace of silica), naturally impregnated with bitumen. Its characteristic color is that of chocolate—which it also resembles in fracture—mean specific gravity 2.235. It is quite hard when cold, and falls to pieces at a heat of about 122°–140° F. At an intermediate temperature it flattens under the blows of a hammer; its structure varies with its locality, but in general should be fine-grained and homogeneous, without particles of unimpregnated stone.

In the poorer qualities the impregnation, though regular, does not exceed 6 per cent., or the bitumen is injected into minute cracks, showing under the microscope that the impregnation is not molecular, or the rock contains *clay*, or, as in the case of Lobsan, the bitumen contains light oils which injure the consistence of the mastic, in which case the light oils are driven off by heat, the remainder being used.

*In Paris, the asphalted sidewalks are universally spoken of as bitumen, in distinction from wheelways, which are called asphalte.

Generally, we may say that the more uniform and microscopic the impregnation of the lime is, and freer from extraneous matters, the better it is.

Neglecting the Tubal Cain stage of its history, asphalte was first applied to sidewalks and wheelways as a mastic, but in that state was not sufficiently resistant for streets of much traffic. It was seen, however, that in summer the pieces of rock that fell from the carts between the mine and the mastic works at Seyssel, compressed under the wheels. In 1849, a Swiss Engineer, M. Mérian, put this lesson to profit, by constructing a Macadam road of asphalte, which was compacted with a roller. In spite of the instability of its foundation and the irregularity of its maintenance, this road is still in very good order. (Malo, p. 108.)

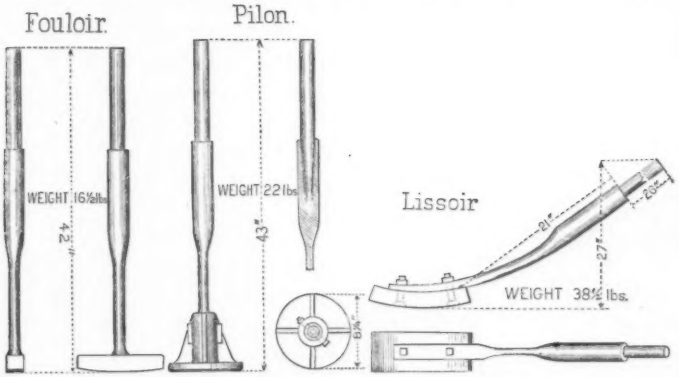
Compressed Asphalte.

The first *compressed asphalte* was laid in Paris by M. Vaudry in 1854, though it was not till 1858 that it was laid on a large scale; the area covered in 1878 by pavements and cross walks was 324 654 square yards, or nearly 14 miles of a street with a 40 feet wheelway. The earlier practice was to "decrepitate" the rock (broken to about the proper size for Macadam) by heating it to about 140° F. in shallow iron pans. Skill was necessary in this operation, as the rock was liable to be burned, *i. e.*, have too much of the bitumen driven off, or to have too little, and sometimes both results were reached in the same batch. The walks in Union Square, N. Y., are an example of the ill effects of unskillful decrepitation.

The rock was also broken up by the direct action of steam, but it was impossible to secure a product of uniform fineness, and difficult to remove all the moisture. After experiments with various machines, a Blake crusher is first used, the pieces are then passed through a Carr's disintegrator, after which the powdered rock is heated in revolving cylinders to from 212° to 284° F. (depending partly on the distance it has to be carried), and transported to the place where it is to be laid, usually in covered sheet-iron wagons.

The permanence of this pavement depends primarily on the stability of its foundation, which is usually of concrete (though old asphalte is sometimes used) 6 inches thick; on this, when it is thoroughly dried, the heated powder is spread, by means of rakes, to such thickness, that when compressed it shall be from 1½ to 2½ inches thick—depending on the probable amount of traffic. The compression, which is termed pilonnage, is effected by the aid of the tools figured. The fouloir is first used

along the junction of the asphalte with either the curb-stone or the paved gutters, while the rest of the surface is compacted by the pilon, beginning with light blows and ending with vigorous ones. All these tools are heated *nearly* red hot, as the powder sticks to them when they are cold. After the surface has been thoroughly compacted it is tested



with a straight-edge, and then rubbed with the lissoir, also heated, giving a glaze to the surface, after which it is dusted over with cement and allowed to cool thoroughly before the traffic is turned on it.

Efforts have been made to secure a more regular surface than is practicable by pilonnage and at less expense by rolling, but it was difficult to so heat the rollers that the powder would not adhere, and the pavement was liable to tear as it was about finished.

The powder retains heat for some time, and the work goes on in a continuous sheet for the day, a gang of ten or twelve men being able to complete about 600 square yards per day. In the morning the uncompressed powder at the edge of the work of the day before is swept away, and hot powder put in its place, which in turn is removed after having heated the old work; the spreading and pilonnage then goes on as before, leaving small or no trace of the junction.

Great care should be taken that the concrete foundation is thoroughly dry, otherwise the hot powder evolves steam, which permeates the powder and leaves the compressed mass in nodules called *almonds*. These do not show during pilonnage, but are developed by the traffic, when the place is cut out and refilled. A very slight defect seems capable of starting a hole in compressed asphalte, and for the first two

weeks it is under traffic it should be watched closely and repaired promptly. The defects caused by deficient aggregation of the molecules show themselves more readily than those caused by steam. Overheating, which renders the asphalte as inert as sand, is one cause of deficient aggregation, and laying the powder too cold is another.

When the asphalte is too rich in bitumen or the bitumen is too oily, the compressed asphalte forms waves under the traffic, sometimes longitudinal and at others transverse.

So far but few asphaltes have been found that are available for compressed pavements. The Val de Travers (from Neuchatel) was first used, but in 1867 Seyssel (Pyrimont) was used with success in the Rue de Richelieu, and both have since been used by the General Asphalte Company of Paris, which, until January, 1878, laid and maintained the asphalte roads in that city. The Val de Travers asphalte is of the two more regular in its grain and impregnation, and richer in bitumen, having 9 to 13 per cent. Seyssel is not so regular in its grain and impregnation, and contains from 7½ to 10 per cent. of bitumen. The base of both is equally pure carbonate of lime, containing about 2 per cent. as a maximum of silica. Of the two, M. Ernest Chabrier, for a long time manager of the Paris Company, in his paper read before the Institute of Civil Engineers, says: "No Engineer could conscientiously say that the Val de Travers is better than the Seyssel asphalte. The former may be safer in the execution of a work not subjected to supervision; the latter offers greater guarantees of good execution, because more care is required in the work."

It was also held that, for compression at least, the two should not be mixed, and that only pure limestone, impregnated with from 8 to 12 per cent. of bitumen, was available for compression; but within the last two or three years the Limmer & Vorwohle Asphalte Company of London found their mastic pavement breaking up and employed the Sicilian asphalte (which is certified by W. J. Fewtrell, F. R. S., to contain as high as 30 per cent. of bitumen) in compressed pavements and sidewalks. Aldgate and Newgate streets having been laid with this asphalte are apparently wearing well. And in Paris, Paul Crochet, who has the contract for new work and maintenance for five years from 1878 (see Appendix, No. 4) has used, so far, a mixture of Lobsan and Seyssel Forens-Nord. M. Malo says of Lobsan: "It contains within its bitumen an oily substance which renders it too soft and injurious to the consistence of asphaltic mastic; we free it from this oil by distillation, after

which it is in a proper state to be used." The Seyssel Forens is a heavy limestone, very poor in bitumen. As after a careful investigation the Engineers of the Ponts et Chaussées have allowed it to be used in Paris, it seems that, theoretically, at least, a mixture of two dissimilar asphaltes is not disadvantageous, nor is the use of an asphalte that contains a hydrocarbon of the more volatile series; also that, as in the case of the Sicilian, an asphalte containing more than twice as much bitumen as was formerly thought the safe maximum, can be successfully laid under exceptionally heavy traffic.

There was an unwillingness on the part of the manager of the Limmer and Vorwohle Company to explain the manner in which he handled his material, but it is probable that it was skillfully roasted so as to drive off the excess of bitumen as his compressed roadways showed less tendency to roll in hot weather than those laid from Val de Travers rock.

By the kindness of Count Kielmansegge, one of the directors of the Neuchatel Company, I am able to give the following analyses of Val de Travers asphalte. These two sets of analyses by Charles Heisch, F, C. S., were made in consequence of complaints by their customers that the rock was becoming too rich in bitumen :

	September, 1876. 5 samples.				
Bitumen.....	9.46	9.48	11.98	11.96	10.06
Carbonate of lime,	90.54	90.52	88.02	88.04	89.94
	100.00	100.00	100.00	100.00	100.00
Loss at 212°.....	1.46	1.42	3.04	3.22	1.92

	July, 1877. 3 samples.		
Bitumen	10.2	11.5	12.32
Carbonate of lime,	89.8	88.5	87.68
	100.0	100.0	100 00
Loss at 212°.....	2.46	2.6	3.2

The loss was moisture and light oils. A small amount of silica was estimated with the lime.

Mr. J. Knight, Secretary Society Francais des Asphaltes, gave me the following analyses made by Steen of Copenhagen :

Seyssel Pyrimont,	Organic,	12.00	Soluble in ether,		9.62
			Insoluble " "		2.35
	Inorganic,	88.00	Soluble in acid,		86.45
			Insoluble " "		1.55
Seyssel Garde bois,	Organic,	9.70	Soluble in ether,		9.15
			Insoluble " "		.55
	Inorganic,	90.30	Soluble in acid,		85.10
			Insoluble " "		5.20

The Garde bois asphalte is only used as a mastic, according to Mr. Knight, not having coherence enough for satisfactory compression.

Mr. W. H. Delano, manager of the Compagnie Générale des Asphaltes de France, says of an asphalte for compression that "it should be carbonate of lime (without admixture of foreign material) and mineral bitumen which does not evaporate at 302° F. Some bitumens contain an oil which commences to evaporate at 158° F.; they may, when purged of the light oil, leave an excellent quality behind. The physical qualities of the limestone should also be carefully examined; but whatever the result of even a careful analysis may be, the value of a new asphalte cannot safely be determined except by actual experience extending over three years, at least, of hard winters and hot summers." Col. Haywood also was understood to say that at least three years were necessary to prove the good qualities of a new or untried asphalte. His experience is strongly against any form of asphalte pavement except "compressed."

From a sanitary point of view an asphalte pavement is without a peer; its surface is smooth, regular and non-absorbent, with no cavities or cracks of any kind to retain the infected mud and dust of the streets, and the soil beneath it is kept dry. It is more thoroughly cleaned, either by sweeping or washing, than any other pavement. Its freedom from noise and other excellencies, is fast placing it in all the business and banking streets of the City of London, where it seems to be superceding all other pavements.

In comparison with granite pavements, its great economy is to brain workers and the owners of horses. M. Darcy estimates that the expense of maintaining and renewing horses and carriages in Paris would be reduced one-half if asphalte was substituted for pavement throughout the city.

Its disadvantages are it is expensive; it is not well to lay it on a grade much greater than two per cent.; it is subject to slight decay in the gutters, which they try to correct in Paris by laying the gutters with stone sets; and lastly, the most serious charge, that it is slippery and dangerous to horses. No doubt at the commencemet of a rain, or in foggy weather, its surface is slippery unless it is very clean, and a horse turned suddenly is liable to fall; but when dry or thoroughly wet no such charge can be brought against it.

Referring to Col. Haywood's much quoted tables comparing granite, asphalte and wood we find that before an accident occurs a London horse will travel on granite 132, on asphalte 191 and on wood 446 miles. "That of those accidents which are most obstructive to the traffic, as well as most injurious to the horses, asphalte had the greater proportion, granite the next and wood the least."

He says further in a report upon asphalte and wood pavements:

"*First.*—As regards convenience: That asphalte is the smoothest, driest, cleanest, most pleasing to the eye and the most agreeable pavement for general purposes; but wood is the most quiet.

Second.—As regards cleansing: That wood may be kept cleaner than it hitherto has been, but will be more difficult to cleanse effectually than asphalte. That as both pavements require occasionally strewing with sand or gravel there is no difference between them in that respect.

Third.—As regards construction and repairs: That asphalte and wood, taking all seasons into account, can be laid and repaired with about equal facility; but the smallest, neatest, cleanest and most durable repairs can be made in asphalte.

Fourth.—As regards safety: That, whether considered in reference to the distance that a horse may travel before it meets with an accident, or the nature of the accident, or the facility with which a horse can recover its footing, or the speed at which it is safe to travel, or the gradient at which the material can be laid, wood is superior to asphalte.

Fifth.—As regards durability and cost: That wood pavements, with repairs, have, in this City, had a life varying from six to nineteen years, and that, with repairs, an average life of about ten years may be obtained; that the durability of the asphaltes is not known, but that under the system of maintenance adopted they may last as long as wood; that, contrasting the tenders for laying and maintaining for a term of years the two best pavements of their kinds, wood will be the dearest."

The above remarks refer to London, and inasmuch as our climate is much the driest, and as asphalte is safer where dry, the comparison would be more in favor of asphalte here than there.

Both the compressed and mastic surfaces are easily and thoroughly cleaned by washing and by sweeping when either wet or dry. A *squeegee*, which is a long-handled scraper, with a rubber blade 32 inches long, when pushed along a wet pavement both cleans and dries it.

It may at first sight seem that if a person will indulge in the luxury of changing his gas company on the receipt of each bill he should be

compelled to make good the surface of the street, and the ease or difficulty of making repairs should largely be a consideration for those who open the streets, but as a matter of fact it is almost impossible to properly inspect the work of plumbers, and while one avenue in this city has on its surface a double tracked horse railroad and 240 elevated railroad columns per mile, with one sewer, three water pipes, and eight gas pipes (belonging to four different companies) under it, the subject cannot be without interest. In general, any pavement with a foundation of concrete can be, and probably will be, more thoroughly repaired than one with a loose foundation, such as sand, broken stones, or Telford. For the surface, asphalte is superior to all others in the matter of neatness, Macadam next, and the granite and wood pavements next.

Asphaltic Mastic.

The asphaltic mastic, which is greatly used in Paris for sidewalks, is made, as above defined, from asphalte and bitumen. This bitumen was at first obtained from the asphalte and molasses of Seyssel by boiling either the broken stone or sand (of the molasses) when the bitumen separated, and was skimmed off the surface of the water and sides of the boiler. This bitumen (after being re-melted and allowed to settle to clear it from sand, if necessary) is melted in an iron boiler to the amount of between 5 and 10 per cent. of the required batch, and the powdered asphalte added slowly and stirred in until all is thoroughly incorporated. It is then cast in moulds for sale or use as mastic. When this mastic is used it is necessary to break it up and add it again to melted bitumen, after which 50 to 60 per cent. of fine or coarse silicious sand is added, and the whole kept heated till it does not stick to a clean wooden stirrer.

The mastic is then taken to the place where it is to be laid, in a *locomobile*, essentially a horizontal cylinder on four wheels, with a fire-box under it and an arrangement for stirring the mastic so as thoroughly to mix the gravel and to keep the mixture from burning. It is then laid on a concrete foundation, generally for sidewalks ½ inch thick, or more. It is poured on the concrete from conical sheet-iron pails, and spread by the aid of a wooden hand float. After the spreading is completed, sand, and in some instances gravel the size of peas, is added, and the surface well rubbed. The sand adds to the wear of the sidewalk, and prevents the mastic softening under the heat of the sun. The mastic is sometimes laid in one course and sometimes in two.

M. Malo insists on the bitumen used for mastic, being the same as that impregnating the limestone, but, on account of its scarcity, it has

been almost entirely replaced by refined and tempered Trinidad or other bitumen.

Crude Trinidad contains, besides water, chips, leaves, &c., twenty-five to thirty per cent. of clay, in which state it is brittle, and the clay, as in the case of compressed asphalte, is an element of weakness, as it attracts water. It is refined, according to Malo, "with goudron," a product of a second distillation of schists, which, at a temperature of 59° to 68° F, has the aspect of a completely liquid bitumen; 600 to 700 pounds of this goudron is boiled in a chauldron, into which the crude bitumen, broken to the size of an egg, is thrown in successive doses until the weight is 1 700 to 1 900 pounds. After the ebullition has ceased the fire is drawn and time allowed for the sand and earth to settle, when the purified bitumen is drawn off and strained. The mineral tar of Autun is said to be the best substance now in the market for refining and tempering bitumen.

M. Malo deprecates the use of oils from boghead coal, and petroleums generally. All of the manufacturers interviewed on the subject denied the use of still bottoms or petroleums, and most agreed with Malo that boghead oils should not be used, on account of the cracks which occurred in the mastic; others claimed that the cracks were due either to a poorer quality of asphalte than they used or to an insufficient purification of the Trinidad. See also App. No. 4, art. 17, and App. No. 5, art. 21.

There is a great difference between the true asphaltic mastics, depending on the purity and quality of the asphalte, the purity and component parts of the goudron and the skill of manipulation. A well made mastic is decidedly harder than compressed asphalte, which to a certain extent is partially fluid under pressure, and increases in density under traffic much faster than the surface is abraded. Mastic, on the other hand, as above stated, is hard, crumbling under too great pressure, not noticably compressible, but disintegrating under the blows of horses' feet. It, however, has much more cohesion than compressed asphalte, and should be preferred in those situations where it is not liable to receive the compressive action of heavy loads and is exposed in large areas to changes of temperature; the partial fluidity of asphalte keeps such cracks closed under traffic.

In the courts of the new House of Parliament, eighty by forty-six feet, Claridge's mastic stands without cracks, a beautiful surface; while carefully laid compressed asphalte in the court next to it has cracks in its surface. Claridge's asphaltic mastic, which has a very high reputa-

tion in London, is made from Seyssel asphalte and a very carefully refined Trinidad goudron It is claimed that the Trinidad bitumen, when thoroughly cleared of its clay, has the greatest cohesive strength of any of the bitumens, and the Claridge Company claim that they conduct their refining processes with more skill and thoroughness than any other company. Their mastic is laid in two courses in strips about 3 feet wide, breaking joints.

It is believed that in Paris no compressed asphalte is laid for sidewalks, but in London the Limmer Company is compressing Sicilian on sidewalks, and the Val de Travers Co. always use compressed.

Some mastic was laid in London streets, but it is now being rapidly repaired or renewed with compressed asphalte, except in narrow streets of small traffic, nor is asphaltic mastic laid in the wheelways of Paris.

There is one theoretical point in regard to different asphaltes to which the attention of the Society may be called. That is the fact that some asphaltes will compress and others will only make mastics. The Val de Travers and the Seyssel are very good for either purpose. Lobsan is capable of being compressed, and with proper treatment, making a mastic. Sicilian, as far as known, has only been employed for compression. The asphaltes of Hanover and Brunswick, while they make very good mastics, seem incapable, with the present knowledge, of being compressed, and the writer has met no one who could explain the cause of the differences. It evidently does not lie in the quantity of bitumen contained in the rock, as some Hanover asphaltes contain more than either the Seyssel or the Val de Travers.

Bituminous Mastic.

Bituminous mastics, or the fictitious mastics of Malo and the French writers, were experimented with very generally in Europe, in the hope of finding something as useful as asphalte at a less price ; but it was found that no practicable degree of heat and pressure would give the microscopic impregnation of grain found in the natural mineral.

In this country the effort took a different direction. Refined and properly tempered Trinidad bitumen was mixed with limestone or fine or coarse sand, and a product was sought between asphalte and asphaltic mastic. It is applied neither as a dry powder nor in a fluid or semi-fluid condition, but as a sticky and coherent mass, and is subjected to pilonnage and rolling. While it does not seem to have either the ductility under traffic or the resistance to wear of asphalte, it has less

hard brittleness than the true asphaltic mastic; its great difficulty being a tendency to disintegrate in a rotten manner, possibly from the use of improper oil in refining and tempering the Trinidad bitumen, or else from the inherent difficulty of making an artificial mixture equal in quality to the natural product.

The most successful pavement of this class in this city is the block on Fifth avenue opposite the Worth Monument, laid by the "Grahamite Company." Its component parts are understood to have been a mixture of Trinidad bitumen with fine sea sand containing a little carbonate of lime, and enough Grahamite or Ritchie mineral "to save the patent." This pavement was laid in the spring of 1873, and after the rectification of surface generally necessary, it stood till the fall of '77 without requiring any repairs that could be charged to its own weakness. It was repaired by another company in the fall of 1878, and now requires additional attention. During this time it has filled all the conditions demanded of a good pavement to a greater extent than any other pavement in the city. Three other pieces laid by this company have not proved so successful.

Pavements of this class are very fully described in General Gilmore's Roads, Streets and Pavements.

They are being extensively laid in Washington under a contract for three years' maintenance. As in France and England, it is held that whatever the physical properties and composition of an untried asphalte may be, it is not safe to pronounce it a success until after three years' wear; it seems that a longer maintenance contract would be advisable.

In London, Colonel Haywood, as noticed under the head of Wood Pavements, lets his asphalte pavements at a certain price per square yard for laying, and a provision that they shall be maintained for 2 years at the contractor's expense and 15 years at an agreed price per square yard per annum, and a good pavement be given to the city at the end of the 17 years.

Several different kinds of pavements, compressed and fictitious and other mastics, were laid, the Val de Travers compressed asphalte being the only one that was satisfactory, and most of the other pavements were relaid by that company at the expense of the sureties. The Limmer & Vorwohle Company, however, introduced the use of Sicilian, with which they have relaid Newgate and Aldgate streets, and are relaying Cornhill.

In the City of Jassy, Roumania, the contract (see Appendix No. 5) is based on the London plan. The work was commenced in 1873 and

finished in 1878. It is to be maintained at the contractor's expense until 1880, from that time, and until 1895, at a stipulated price.

In Paris (see Appendix No. 4) the system is to let the construction, maintenance, and repairs of pavements and footpaths for a term of years, 5 to 10, without guarantee of wear, relying on rigorous specifications and thorough inspection for the excellence of the work.

The plan pursued in London and Jassy seems preferable, even with the natural asphaltes, for after the solidity of the foundation is assured, the duration of the wheelway depends so much on the technical skill and thorough honesty exhibited in small details, that the burden of proper inspection should be thrown on the contractor by his having a large pecuniary interest in the soundness of the work done and material furnished. The inspection, however, should be close enough to keep the Engineer in charge fully informed of the methods and materials employed, particularly towards the close of the contract. But no greater injury could be done to a city's system of streets than strictly enforcing the specifications of some of the 300 and more patents taken out for mastic pavements.

The possibility of having any street in continuous good order for 17 years is probably too much for the imagination of the average New Yorker. And no one can well realize the effects of having all the streets so kept in repair.

Tar Mastic.

Among the legacies of the "ring" were the various tar pavements. They were worse than the wood pavements, though not being so thick, they have not proved so enduring a nuisance as the latter.

The best of them are understood to have been made of crude coal tar mixed with gravel and sand, and on the evaporation of the light oils they went to pieces, generally with great celerity. Occasionally a patch would be found that stood the traffic pretty well; this was supposed to result from the evaporation of the oils before mixing with the gravel. G. Leverich, Member of the Society, proposed to secure a uniform product by passing steam of a certain temperature through the tar and driving off all the oils of low specific gravity. Coal tar is now generally reduced to pitch to get the aniline colors, their most valuable product, and the pitch may be tempered by melting with dead oils, a waste product of the distillation. It, however, is very brittle, and it is doubtful if it can be employed economically, except for side-walks of light traffic.

APPENDIX No. 1.

Extract from Specification of W. S. Till, Borough Surveyor, Birmingham, 1877.

The whole of the carriage way to be excavated to the required depth, and the foundations formed to uniform gradients and proper cross sections, with ashes or other approved materials. When these have been rolled and are well set, the contractor to coat the whole width and length of the carriage way with not less than 8 inches of good, strong, clean gravel, screened through a ¾ inch riddle, or with not less than 8 inches of approved slag, broken regularly to such a size that the largest piece, on its greatest dimension, will pass through a 3 inch ring.

The gravel or slag to be well gritted and watered, and kept raked together and rolled until the whole is consolidated. * * * * * * *

The contractor to coat the carriage way, throughout its whole length and width, with not less than 6 inches of Rowley Ragstone, broken to pass through a 2½ inch ring.

The stone to be gritted, watered, and kept together, raked and rolled until the whole is consolidated. Crown 6 inches above curbstone. Each layer to be laid on complete throughout the whole length and width of carriage way, and each layer to be separately rolled with a heavy roller.

APPENDIX No. 2.

Extract from Specification for Telford Macadam and Trap Block Gutters on Fifth Avenue.

(4.) DESCRIPTION OF MATERIALS.—The stone blocks are to be of durable and uniform quality, each measuring, on the face or upper surface, not less than 4 nor more than 8 inches in length, and not less than 4 nor more than 6 inches in width, and in depth not less than 6 nor more than 8 inches; blocks of 4 inches in width on their face to be not less than 3 inches in width at the base; all other blocks in transverse measurement on the base, to be not more than 2 inches less than on the face, but no block on the base shall be of less width or length than 3 inches, and to be in all respects equal to the specimen blocks at the office of the Commissioner of Public Works.

It is also required that the sides of the stones (which form the joints) shall be so sufficiently even and properly shaped that joints may be formed with a similar side not exceeding ½ of an inch, no stone having an objectionable protruding face will be accepted or allowed to be used for paving. They will be carefully inspected after they are brought on the line of the work, and all blocks which, in quality and dimensions, do not conform strictly to these specifications, will be rejected, and must be immediately removed from the line of the work. The contractor will be required to furnish such laborers as may be necessary to aid the inspector in the examination and culling of the blocks; and in case the contractor shall neglect or refuse so to do, such laborers as in the opinion of the Commissioner of Public Works may be necessary, will be employed by the said Commissioner, and the expense thus incurred by him will be deducted and paid out of any money then due or which may hereafter grow due to the said contractor under this agreement. The blocks must be of trap rock or of syenite, equal in hardness to what is called Quincy granite.

TELFORD.—The stone for the foundation of the pavement is to be sound hard and durable quarry stone, each from eight to ten inches in depth, from three to six inches in width, and from six to fourteen inches in length, and of a sufficiently uniform size to be acceptable; except the stone under the gutters, which only differ from those above described in that they must be not less than six inches in depth and except the course of stone under the Macadam, which is next to the gutters or the bridge stone, which stone is to be twelve inches in depth, and in every other respect as first above described.

The broken stone for the bottom course is to be of trap rock, and of such size that would pass in any direction through a ring with interior diameter of 2½ inches, and of a sufficiently

uniform size and proper shape to be acceptable, to be composed only of stone that is hard and durable and sufficiently free from screenings and practically free from dirt and other foreign matter. The broken stone composing the next overlying course is to be the same in every respect as just described, except that each stone is to be of such size that would pass in any direction through a ring with interior diameter of 2 inches.

The coarse screenings are to be those of trap rock; the stone is to be practically free from dirt and other foreign matter, to be composed of material only that is hard and durable, no particle of which is to be of larger size in any direction than 1¼ inches and all the particles to be of such relative size to 1¼ inches as shall be acceptable; through these screenings is to be evenly mixed before rolling a sufficient quantity of the finer screenings of trap rock to form a proper and secure bond.

The fine screenings of trap rock are to be practically free from dirt and other foreign matter, and to be composed of material both as to size and quality that will be acceptable.

(9.) Preparation of Road Bed, &c.—All paving and other stones necessary to be removed shall be taken up and immediately removed from the line of the work; the Belgian and granite blocks to be deposited where directed by the Water Purveyor for the use of the City; the subsoil or other matter (be it earth, rock or other material) shall then be excavated and removed, to such depth to be determined by the engineer in charge, that when rolled and finished, irrespective of the covering of fine screenings, the pavement throughout its entire extent shall be at least sixteen inches thick. Should there be any spongy material or vegetable matter in the bed thus prepared, all such material shall be removed, and the space filled with clean gravel or sand carefully rammed or rolled, so as to make such filling compact and solid. No ploughing will be allowed in preparing the foundation.

The road bed shall be truly shaped and trimmed to the required grade, and with such crown as shall be directed by the said engineer, and rolled with a roller weighing not less than two tons, until the surface is firm and compact.

Laying the Foundation or Pavement.—After the road bed is prepared, agreeably to the terms of this specification and to the satisfaction of the engineer, and the stone hauled and deposited thereon, the foundation stones shall be laid by hand in the form of a close, firm pavement. They shall be set on their broadest edges and lengthwise across the road, except in the case of the stone under the Macadam, which is next to the gutter stones or bridge stones, which foundation stone is to be placed with its longest side parallel to the curb or bridge stone; after being set closely together, they are to be firmly wedged by inserting and driving down, with a bar, in all possible places between them, stones, as near as practicable, of the same depth, until all the stones are bound and clamped in proper position; all the projections and irregularities of the upper part of the pavement shall then be broken off with a hammer, care being taken not to loosen the pavement, and the spalls and chips are to be worked and driven with the hammer into all the interstices not already filled by the process of wedging, so that the pavement, when completed, shall present a sufficiently even surface, and be at each point of such thickness as required by these specifications. No wedging shall be done within twenty-five feet of the face of the work that is being laid, and the stone foundation must be in a compact and satisfactory condition in every respect at the time of the spreading of the broken stone.

Macadamizing.—After the stone foundation has been completed agreeably to these specifications and has passed the inspection of the said engineer, a layer of broken stone of the quality and size herein specified for the bottom course, and of such a depth as will make 4 inches when rolled, shall be spread evenly over the pavement; this layer is then to be rolled until sufficiently compact.

The next overlying course will be of stone, as hereinbefore described for said course, and is to be spread so that the surface will be uniformly 1 inch below the grade and crown when the pavement is finished.

Stone hammers are to be used on this course, so that when rolled as much as shall be required, the surface of each stone that is exposed will not have a longer dimension in any direction than 1 inch.

A layer consisting of the coarse screenings herein specified is then to be applied and spread to such depth as will bring the surface to the proper grade, irrespective of the finish of fine screenings; this layer is then to be rolled, and during the progress of the rolling, if necessary, coarse screenings shall from time to time be applied, so that when the rolling ceases the roadway is truly surfaced to the required grade and crown. This layer is to be rolled until all settlement ceases and the stones are thoroughly compact and the surface true to the grade and crown.

During the process of rolling any course of stone there shall, when required, be spread lightly over the same from a shovel, the fine screenings of trap rock herein described; and after the upper layer has become thoroughly compact, there shall be spread upon the surface fine screenings, so much as to produce a covering half an inch in depth when rolled, and the rolling is to continue until, by a sufficient use of water, a wave is produced before the wheel of the roller.

The rolling of the Macadam stone and screenings shall be done with a roller weighing not less than any of the steam rollers in the possession of the Department of Public Works.

Each layer of broken stone and the screenings or binding material shall be well and thoroughly rolled, and the rolling upon each layer shall be prosecuted until, in the opinion of the engineer, each course shall have been completed, as hereinbefore specified, and until each layer and the finished surface shall be rolled and finished to his entire satisfaction and approval.

While the rolling of each layer of broken stone and the screenings or binding material is being prosecuted the work shall be kept moistened to such extent and in such manner as required, and care shall be taken that too much water is not applied while rolling the first layer, and until after the interstices are well filled with the binding material.

The pavement, when completed, shall be at each point of such construction and at least of such a depth as required by the specifications, and of such crown and such form of gutter as shall be directed, and in any case the thickness of the pavement is to be determined on a line at right angles to the grade and crown.

The use of a proper roller, rammers, or other suitable implement, is to be substituted for that of the steam-roller when necessary.

The construction of the foundation stones, and the Macadam pavement shall proceed so as to be practically equally as far advanced across the entire width of said pavements.

Particular care and attention will be required in obtaining a satisfactory joining of the macadam paving and the blocks in the gutters.

PAVING THE GUTTERS.—Upon the stone foundation already described, shall be laid a bed of clean, sharp sand, not too fine, or clean fine gravel, of the depth necessary (about 4 inches), to bring the paving to the proper shape and grade when rammed. The stone blocks are to be laid with joints at right angles to the curb, with joints not exceeding three-quarters of an inch, at such grade and in such form as shall be directed; each course of blocks shall be of a uniform width and depth, and so laid that all longitudinal joints shall be broken by a lap of at least one inch; and the blocks next the curb shall break joints with the curb by at least one inch; as the blocks are laid the joints shall be so filled with sand or gravel as to secure, when the work herein mentioned is completed, against their being any spaces not filled with sand or gravel between the blocks; they shall be covered with clean, sharp sand, which shall be raked until the joints become filled therewith, the blocks shall then be thoroughly rammed to a firm unyielding bed, with a uniform surface to conform to the grade and crown of the avenue, as shall be directed. No ramming shall be done within 25 feet of the face of the work that is being laid; and the ramming is to be done at such times and in such manner with reference to the rolling as shall be directed. When the paving from the centre of an intersecting street to the centre of the next intersecting street is constructed, it shall be covered with a good, sufficient second coat of clean sand, and shall immediately thereafter be thoroughly rammed until the work is made solid and secure, and so on, until the whole of the work embraced in this contract shall have been well and faithfully completed in accordance therewith.

This portion of the work, laid with trap blocks for the gutters, will be measured and included in the returns for Macadam pavement.

No stone or other material, except sand or granite, is to be placed on the blocks that are paved, until these are rammed. When necessary, in order to make good joints, the blocks are to be trimmed down on the sides by and at the expense of the contractor.

APPENDIX No. 3.

ROAD ROLLERS.

As far as known to the writer, the 4 rollers here described are the only ones in the market; they all run with equal facility with either end forward.

THE GELLERAT ROLLER.

These machines (see Plate XXVI), consist essentially of a locomotive boiler, supported on a frame which is carried on two cast-iron rollers, each 3 feet 11 inches in diameter, and 4 feet 7 inches long for the 15-ton rollers, and 4 feet 9 inches in diameter and 6 feet long for the 30 ton rollers. Their peculiarity is that each roller is a driving wheel, and bears half the weight of the machine, which is guided by a hand wheel working from the foot-board into a bevel gear S, Fig. 2, which works the right and left hand screws, *R R*, throwing the axes of the rollers into radial positions; the other, or driving end of each axle, is stationary, with a spherical bearing—*M*, Figs. 1 and 2.

THE LINDELOF ROLLER.

This roller (see Plate XXVII.) has an upright boiler, and two vertical cylinders that actuate a beveled gear which works into a gear bolted onto the driving wheel, the tread of which is a 1 inch plate of wrought iron; the driving roller bears two-thirds of the weight of the machine. Both 10 and 15-ton rollers are built; for the 10 ton, of 2 000 pounds each, the driving roller is 6 feet and the steering roller 5 feet long, giving a weight on the driving roller per inch run of 185 pounds.

THE ROSS ROLLER.

This machine (see Plate XXVIII.) is a combined road roller and rammer. Only one size is built, weighing 44 000 pounds. The boiler is vertical and the rams, any or all of which can be used or not, are actuated by cams. The length of the driving roller is 8 feet in all, with a space in the middle of 8 inches for the driving chain. The steering roller is 30 inches long. Four-fifths of the entire weight is carried by the driving wheel, giving a compressive force per inch run of 550 pounds. It is claimed that the traction is sufficient to allow it to mount grades of 20 feet per 100. Maximum speed, 5 miles per hour.

The rams, five in number, are said to give an effective blow of 7 000 pounds each; they are of no use in compressing and puddling trap, but are efficient with limestone, and must be efficacious for rubble foundations. The frame is utilized as a water tank, and the driving roller can be heated by steam for rolling mastics, &c.

THE AVELING AND PORTER ROLLER.

This roller, which is extensively used in this country, has been improved in several particulars, and is believed to be the only roller now in the market that is run and fired by one man.

As now manufactured (see Plate XXIX), the outside wheels are the driving wheels, the steering wheels covering the space between them. The boiler is horizontal and multitubular; the single steam jacketed cylinder is on top of the boiler, and runs a fly-wheel which by the aid of gearing drives the roller at a speed of about 2 miles per hour. The driving wheels have holes in their treads in which spikes may be placed for tearing up the road bed before remetaling, and the fly-wheel makes the roller available as a stationary engine to run a stone breaker.

Four sizes are manufactured, viz., 8, 10, 15 and 20 tons in weight. Two-thirds of the weight is carried on the driving wheels, which have a width of 2 feet 2 inches for the 20 ton roller, giving a weight per inch run of 574 pounds; the width of driving wheels on the 15 ton roller, is 1 foot 10 inches, giving a weight per inch of 509 pounds. The roller is fitted with a friction brake.

APPENDIX No. 4.

A part of the Contract for the Construction and Maintenance of the Streets and Sidewalks of the City of Jassy.

Between M. Nicholas Gané, Mayor of Jassy, and Mr. W. O. Callender, of London.

ARTICLE 1. The contract has for its objects:

(*a.*) The construction of a system of streets with gutters and a system of sidewalks with curbs.

(*b.*) The maintenance of the streets and sidewalks constructed under this contract.

ART. 2. The construction consists of the following items of work:

(*a.*) The construction of 47 853.8 square yards of streets, covered with compressed asphalte.

(*b.*) The construction of 179 384.3 square yards of sidewalks, covered with asphaltic mastic.

(*g.*) The construction of 17 038.4 square yards of roadway, paved with Macadam made from stone taken from streets now paved.

(*h.*) The construction of 49 210 lin. feet of granite curbing for bordering the asphaltic mastic sidewalks on streets covered with compressed asphalte.

ART. 3. The time fixed for the completion of this contract is five years, to begin with July 1st, 1873, and to end on March 31st, 1878.

ART. 5. The labor of maintenance will consist in maintaining the streets in a constant good condition. On all the streets and sidewalks constructed by him, the contractor will repair, with his own laborers and his own material, all degradations as soon as they appear, and will replace the material lost.

ART. 6. The length of the contract for maintenance is fixed at 15 years, to begin on May 1st, 1880, and to end on April 30th, 1895.

ART. 10. The transverse inclination of the asphalte sidewalks will be 2 per cent.

ART. 11. The curbs of sidewalks of asphalt, on asphalted streets, will be of granite; those of sidewalks of asphalte, on streets paved with blocks or cobble stones, will be of sandstone, and the curbs of Macadam streets, when they protect sidewalks of the same material, will be of stone cut from the old flagtones of the present sidewalks.

The curbstones will be of the following dimensions: The faces parallel to the surface of the sidewalk will be 5.5 inches in width, of which 0.9 inches of the upper face will be eventually covered with asphalte. They will have a height of 11.9 inches, of which 6 inches will be under ground and the remainder above the gutter; their length will not be less than 15¾ inches. The form of the curb will be that of a parallelepipedon, having next to the sidewalk a rebate of 0.9 inches in width and a height equal to the thickness of the bed of asphalte.

ART. 14. The gutters of asphalted streets shall have, according to the locality, a maximum width of 3.3 feet; they shall be constructed of new cobble stones, well culled, or of new sandstone blocks. At the edge of the asphalte there will always be laid a range of granite blocks 10.6 inches in length, 5.3 inches in width, and 9 inches in depth.

ART. 15. The sandstone blocks for the gutters will be dressed to regular cubes in form, of 9 inches on each side.

ART. 16. The asphaltic rock, which must be natural and not artificial, must be from the best asphaltic quarries known: Limmer, in Hanover, Seyssel, in France, and Val-de-Travers, in Switzerland. The asphaltic mastic to be used must satisfy the following conditions:

(*a.*) It must contain 12 parts of bitumen to 88 parts of asphaltic rock.

(*b.*) The asphaltic rock itself must contain at least 7½ per cent. of bitumen, and at the most 23 per cent. of pure carbonate of lime.

(*c.*) Rocks which contain, even in small proportions, quartz, sulphates, iron pyrites or aluminum must be rejected for the composition of mastic.

ART. 17. The bitumen used for mastic must be natural, not artificial, from the bitumen lakes of the Island of Trinidad, or from the asphaltic rocks of Seyssel, if it is proved to be equal in quality to the Trinidad bitumen: it must be free from water; its specific gravity must be from 1.1 to 1.5. Dipped in water at the freezing point, it must not lose its ductility; its surface must present no cracks or streaks. The surface of a fracture must be black and brilliant. It must be perfectly soluble in petroleum oil or the spirits of turpentine, and the solution when passed through a filter must leave no residue (?)

ART. 18. The quarry whence comes the bituminous rock, the mastic and the bitumen must be certified by authentic certificates to be of even fabric and its products of the first quality. Each block of mastic must bear the trade mark of the quarry.

ART. 19. The contractor is forbidden to have in his storehouses any asphaltic rock or mastic which do not comply with the conditions above stated, and not in conformity with the samples deposited with the Mayor on the day of the signing of this contract; he must neither use nor have in his storehouses any bituminous or resinous oils other than those specified in Article 17.

All other material, resinous, bituminous or oleaginous and all other mastic than that like the samples deposited with the Mayor that may be found in the storehouses of the contractor will, on the first offense, be confiscated, and a fine of 1 000 francs be imposed; in case of a repetition of the offense, confiscation and a fine of 5 000 francs; and should it occur a third time, besides the confiscation, the contract will be relet at the expense of the contractor's surety.

ART. 20. The gravel employed in mixing the mastic must be taken from the beds of streams; it must be thoroughly cleansed of all foreign matter, well washed, free from argillaceous matter, and must be passed through a screen, the holes of which do not exceed 0.2 inch.

ART. 21. The sand for making the mortar for beton, and for forming the bed for asphalte, even that employed for bedding the street pavements, the gutters or curbs, shall be sharp, hard to the touch, and will be procured from the best open or working pits, or from the bed of running water.

ART. 22. The cement will be the best from the best known quarries, such as Stefanesti or Rodeni.

ART 23. The stone used in mixing the beton will be broken stone from the quarries of Paun or Barnova. Each piece must pass through a ring of 2.4 inches diameter; it shall be free from all foreign matter and well washed.

ART. 24. The granite shall have the following qualities:

(*a.*) It will be obtained from the hardest seams of the quarries; it shall be homogeneous, sonorous to the blow of a hammer, without flaws or fractures, and free from foreign matter.

(*b.*) It shall have a specific graviiy of 2.65.

(*c.*) After an immersion of 24 hours in water, it must not absorb more than $\frac{1}{150}$ of its volume.

(*d.*) When struck a hard blow, it must break in large fragments without leaving any detritus.

ART. 25. The sandstone shall be provided from the hardest beds of the quarries in Roumania. The qualities of the sandstone shall be as follows:

(*a.*) Under the blow of a hammer, the sound of the stone must be limpid and pure; a dull sound would indicate interior fissures, and would be sufficient to reject it.

(*b.*) The specific gravity shall be 2.5.

(*c.*) After an immersion of 24 hours in water, it should not absorb more than $\frac{1}{40}$ of its volume.

ART. 26. The limestone for the beton shall be of the hardest quality, chosen from the hardest beds.

ART. 27. The mortar for the beton of the sidewalks shall be composed of two parts of sand to one part of cement in volume. It shall all be mixed and wet with only as much water as may be absolutely necessary. Mortar which may set before being put in place will be rejected. The composition of the mortar for the beton which is to be used on the streets remains to be described hereafter, as also the compressed asphalte.

ART. 28 The beton will be composed of 3 parts of broken stone to 2 parts of mortar.

The beton which is not used after it is prepared will not be accepted.

The streets which are to be covered with compressed asphalte shall be constructed in the following manner:

(*a.*) The levels will be corrected, the ground shall be shaped to the form of the transverse profile fixed by the City, and will be sprinkled and rolled until it presents a smooth, hard surface.

(*b.*) The curbstones shall then be set, care being taken to cut the joints on the ends as well as on the front edge.

(*c.*) The part corresponding to the gutters will then be made of a bed of sand 2.4 inches in depth, in which will be laid the stones which form the gutters; the sides of the gutters next to the bed of asphalte will in every case have a range of granite blocks. The remainder of the width of the gutters shall be paved with cobble stones, well assorted, in such a manner that the stones will all be of the same size, or with new sandstone blocks, agreeably to the City authorities. The gutters thus laid shall be well rammed with a rammer and over all shall be spread a layer of sand 0.4 inches deep.

(*d.*) That portion of the street which is to be covered with asphalte, will receive a bed of beton, the depth of which, after pilonnage, shall not be less than 6 inches. Upon the beton shall be spread a layer of brick broken to 0.4 inches in size.

(*e*) On this shall be laid the compressed asphalte, when the foundation shall have reached the the desired consistency and become well dried.

(*f.*) The asphalte will be laid according to the methods usually adopted on works of a similar nature ; the method of doing this remains to be discussed at a future day by the City and the contractor.

ART. 33. The surface of the sidewalks shall be done over when needed, sprinkled and rolled ; over this shall be laid a bed of beton which after compression shall not have a less thickness than 3 inches. On this shall be spread the mastic to a depth of 0.8 inches. This mastic shall be composed of asphaltic mastic, gravel and bitumen in the following proportions: asphaltic mastic 100 parts, gravel 60 to 72 parts, and bitumen 6 to 10 parts. The mastic and bitumen shall be melted in a portable kettle, so that they may be carried to the spot where they are to be used. The mastic shall be broken into small pieces and shall not be poured until it is entirely melted. During the melting the mastic shall be kept stirred, so that a thorough mixture may be ensured and the mastic not allowed to burn. The mastic thus prepared shall be run over the beton in such a manner as to spread evenly over it. Before the complete solidification of the mastic which forms the surface, sand will be spread over it and fixed by light ramming. At the junction between a cold and a hot bed, the edge of the cold one shall be reheated by spreading over it a coating of melted bitumen that will then be removed and the final bed laid.

ART. 34. The tempering of the mastic should be such that it will support, at a temperature of 77 Far., the point of a rectangular pyramid of a height equal to one side of the base, without a depression occurring greater than 0.2 inches under a pressure of 154 lbs. continued for five minutes.

ART. 35. The sidewalks at carriage doorways shall have a foundation of beton 4 inches in depth after ramming, and the bed of mastic will be 1.2 inches.

ART. 37. The junction of the mastic with the walls of the buildings bordering the streets will be made by means of a skirting, that is to say, the plaster will be scraped from the walls of these houses to a height of 2 inches above the level of the sidewalks, and the asphalte will be plastered on the bricks to the thickness of the mortar.

The junction of the stratum of mastic with the posts, curbs, hydrants, and other objects of various natures will be made by heating these objects by a coating of melted asphalte that will be then removed and the final bed laid.

ART. 42. The blocks and the cobble stones that the City authorities may declare unfit for using again will be broken and used as Macadam on streets designated by the City ; they shall be constructed as follows :

(*a.*) The ground shall be well graded, giving it the form and inclination of similar streets.

(*b.*) On the surface thus prepared there shall be laid first, gutters of cobble stones to a width of from 2.5 to 3 3 feet. These shall be laid as specified for streets paved with cobble stones.

(*c.*) On that portion of the ground designed for the roadway there shall be spread a bed of broken stone of 6 to 8 inches, reducing, after wetting and ramming, to 4 to 6 inches in depth.

(*d.*) On this strata of stone there shall be spread a bed of sand, which shall be well wet and rolled, so as to obtain a smooth and uniform surface.

ART. 49. * * * * From the provisional reception, the maintenance of the work completed will be performed by the contractor till April 30th, 1880.

ART. 50. All unexpected degradations, all badly executed work, not only during the progress of construction, but also during the years of maintenance, will be repaired by the contractor, whatever may be the cause of the degradation, and with the least delay, without waiting to be notified by the city, under penalty of a fine of 50 francs for each day of delay after the three first days which follow that of the discovery of the degradation.

Besides that penalty, if the contractor does not proceed immediately to the reparation of these unforeseen accidents, the city shall have the authority to put them in good repairs in his place and at his expense, by deducting the cost from the estimate.

ART. 51. On April 1st, 1878, the city will make a new and minute inspection of all the work done during the five seasons. They will compare the state of the work done with that of each of the estimates made at the end of each season, and if it be found that the works are in compliance with this contract, and in good condition, they will finally accept them and make out a new estimate, of which a duly certified copy will be furnished the contractor.

ART. 52. On May 1st, 1880, the contractor having satisfied the first part of the obligations devolving upon him under this contract, binds himself under a new obligation to the city, that of maintaining for a period of fifteen years, from May 1st, 1880, to April 30th, 1895, the works executed, in consideration of a price agreed upon in advance.

ART. 53. The maintenance consists in repairs, renewals and furnishing materials necessary to the sidewalks, curbs, gutters, &c.; in doing all kinds of work and furnishing materials necessary to at all times maintain the surface of the streets and sidewalks paved by the contractor, in a perfect state of uniformity.

The unformity of the surface of the streets and sidewalks shall be determined by the use of a templet of iron formed to the normal curve adopted for the surface of the streets and sidewalks. This templet, applied to a street or sidewalk, must not present at any point a swell or depression greater than 0.4 inches.

The surface of the streets and sidewalks shall not show any cracks. The connections with the curbs must be perfect.

ART. 54. Whenever the curbs, the sidewalks, the roadways, the water ways—in a word, everything that goes to make a part of the street, become subject to a displacement or derangement from any cause whatever, the contractor will be obliged to repair them immediately, in conformity to the preceding article. Exception is made, however, to all that applies to the construction or repairs of water or gas mains, which will always be at the expense of the respective grantees.

ART. 55. The contractor shall proceed at once, at his own cost, to repair any degradation whatever, without notification from the city.

Whenever a notification from the city becomes necessary to warn him to proceed with the reparation, the contractor will be liable to a fine of ten francs, and he will be obliged to proceed with the reparation within 24 hours after the receipt of such notification.

If, after that notice, the contractor fails to proceed with the repairs of the degradation indicated by the city, the latter shall proceed with the work; it shall make the reparation, submit the contractor to a fine of fifty francs, and retain the cost of the reparation and fine from any sums that may accrue for the maintenance of the streets, and in case that should not be sufficient, from the sureties.

In case of a repetition of this offense occurring during the course of a single year, the city, besides the right which it always reserves to make the reparation on the account of the contractor, in conformity with the preceding paragraph, will impose on the contractor a fine of 1000 francs.

Finally, on a third infraction in the course of the same year, the city has the right to make, besides the reparations after the rules established above, and of re-letting the work of maintenance to another at the cost of the contractor; if this sale results in a loss to the city, it shall have the right to reimburse itself from the sureties. In case, on the contrary, it results in a profit, the contractor shall have no right to demand it.

ART. 59. The prices for the works executed in conformity to the requirements of this contract shall be :

(*a.*) For compressed asphalte $5.38 per square yard.

(*b.*) For sidewalk asphalted, $2.81 per square yard.

(*c.*) For roadway, with gutters, paved with sandstone blocks taken from streets now paved, $1.94 per square yard.

(*d.*) For roadway or gutters paved with new sandstone blocks furnished by the contractor, $8.41 per square yard.

(*e.*) For roadway, the gutters included, paved with cobble-stones taken from streets now paved in that manner, also for gutters constructed with cobble-stones on Macadamized streets, $1.02 per square yard.

(*f*) For roadway paved with cobble-stones furnished by the contractor, also for gutters paved in this manner on streets covered with compressed asphalte, $1.91 per square yard.

(*g*) For Macadam roadway, $1.45 per square yard.

(*h.*) For granite curb to asphalted sidewalks, $0.95 per lineal foot.

(*i.*) For sandstone curb to asphalted sidewalks, $0.67 per lineal foot.

(*k.*) For curb cut from the old sandstone slabs or flags, $0.39 per lineal foot.

(*l.*) For granite curb used in the edging for asphalte of streets, $0.81 per lineal foot.

ART. 57. The price for maintaining the roadway and sidewalks during 15 years from May 1st, 1880, to April 30th, 1895, shall be calculated from the total area constructed by the contractor, and shall be as follows :

(*a.*) For maintaining compressed asphalte streets with granite curb, $0.09 per square yard per annum.

(*b.*) For maintaining asphalte sidewalk, whatever the kind of curb, $0.04½ per square yard per annum.

(*c.*) For maintaining roadway or gutter paved with old or new stone blocks, $0.29 per square yard per annum.

(*d.*) For maintaining roadway or gutters paved with cobble-stones, $0.09 per square yard per annum.

(*e.*) For maintaining Macadam, including the sidewalks and curbs, $0.15 per square yard per annum.

ART. 58. Payment for work done will be made to the contractor in the following manner; One-quarter of the work done will be paid for in cash, the remainder in City bonds.

The bonds will have 15 years to run; they will bear interest at 6 per cent. per annum, payable semi-aanually; they will be delivered to the contractor at par.

ART. 67. The sums due for the maintenance of streets and sidewalks during the 15 years which follow the construction—from May 1st, 1880, to April 30th, 1895—will be be paid by the City of Jassy, at the end of each month, after deducting all that the contractor owes to the City for repairs made in his name and at his expense, and fines. These payments will be made in cash.

ARTS. 69 to 71, inclusive, provide that the contractor shall place a guaranty of 100,000 francs in bonds of Roumania, which may be replaced by bonds of the City. In addition 10 per cent. of the contract price shall be retained, until the sum of 400,000 francs is reached, making a total guaranty of 500,000 francs. This guaranty shall be returned to him as follows: May 1st, 1878, 250,000 francs; and at the end of the years of maintenance, May 1st. 1895. 250,000 francs.

ART. 72. Six months before the expiration of the fifteen years of maintenance, the City authorities will make a general inspection of all the work done and maintained and make an estimate of it.

ART. 73. If during this inspection the City discovers the necessity of any repairs, the contractor shall do the same at his own expense during the following six months, in such a manner that the streets maintained by him shall be turned over to the City in a good condition on the day the contractor completes his contract.

Should the contractor refuse to make these repairs, the city shall proceed to do it at the expense of his warranty.

ART. 74. At the end of the 15 years of maintenance, if the streets are in a good condition, considering only the effects of the weather, but presenting no degradations, the final acceptance of the works will be made and the guaranty deposited by the contractor returned to him.

The coupons of bonds deposited as guaranties are the property of the contractor, who will have the right to collect the sums corresponding to each. The contractor shall also have the right to replace the bonds deposited by him as guaranty whenever they may become extinguished through the process of drawing lots.

ART. 89. The system allowed for the pavement of the carriage ways is that of compressed asphalte. The manufacture of this compressed asphalte will not depart from the rules actually adopted by science and experience, the mode of execution of the compressed asphalte remains to be agreed upon hereafter between the City and the contractor.

APPENDIX No. 5.

Abstract of Specifications and Schedule of prices for the construction and maintenance of foot-paths and sidewalks, in asphaltic mastic, and the Places and roadways in compressed asphalte belonging to Municipal service of Paris, from January 1st, 1878, to December 31st, 1882. Paul Crochet, Contractor.

ARTICLE 1. The work has for its object—1st. The maintenance and construction of foot paths and sidewalks in asphaltic mastic, situated in the public ways. 2d. The maintenance and construction of compressed asphalte pavements. 3d. The new works; these works will comprise all the pavements in bitumen and asphalte.

ART. 4. The present letting is made on a scale of prices, and the amount of the work is completely undefined, so that the contractor cannot make any demand on account of any changes that the expenditure may be subject to.

ART. 6. When the adjoining proprietors or other parties in interest have to bear the cost of the works detailed above, or to contribute in any proportion, the contractor will be held to execute the work at the same price as that done at the cost of the City of Paris, and conformably to the orders of the Engineers.

ART. 7. Foot pavements shall have the widths determined by the administration, they shall be composed of pavement in mastic supported on the side of a public road by a curb the height of which shall commonly be of 6½ to 4 inches.

ART. 9. The ordinary curbs in granite shall be 11¾ inches wide on top with a total fall across of ¾ inch; 13 inches wide at the base, which shall be horizontal; 11⅞ inches high on the front face which shall have a batter of 1½ inches.

ART. 16. The mastic pavements will be formed of a layer of pure asphaltic mastic at least $\frac{9}{16}$ inches thick, resting on a bed of hydraulic concrete 4 inches thick which comprises a covering of hydraulic mortar at least ¾ inches thick.

ART. 17. The compressed asphalte pavements will consist of an upper layer of compressed asphalte 1½ to 2½ inches thick, resting on a foundation of hydraulic lime or cement, concrete 4 to 6 inches thick covered as above with mortar or upon an old Macadam roadway picked over and covered with a thin coat of hydraulic mortar.

ART. 21. The asphaltic mastic employed either for new or repairing old paving shall be composed of naturally impregnated rock with natural bitumen of good quality, coming exclusively from mineral rocks.

The fictitious bitumens extracted by the purification of the heavy oils of schists, the distillation of coal, those so-called fatty bitumens and all other analogous products shall be rigorously proscribed.

The rock employed after being reduced to powder will be melted with a sufficient quantity of purified natural bitumen to form a mastic which, when cold, presents a homologous mass slightly elastic, and which does not soften under a hot sun. This mastic shall be moulded into blocks. There may also be used blocks of bituminous mastic with a base of slates manufactured by the process of M. Sebille.

ART. 22. The contractor shall be bound to employ under the orders of the Engineer upon each public way the bituminous mastic above described.

The mastic shall be formed of a mixture of natural bitumen, in the proportion of one-twelfth of its weight at most, and the calcareous asphalte rocks of Seyssel, Seyssel-Forens, Pyrimont or Volants, of Val de Travers or Lobsan, or others deemed equivalents by the Engineers.

The mastic, having a base of slate of M. Sébille, will be formed of a mixture of bitumen described in Art 23, following, and of powdered red or blue slate of Ardennes, powdered chalk of Meudon or of Nanterre and of silica from the basin of Paris, in the following proportions, by weight:

Refined mineral bitumen	30
Ground slate	35
Powdered chalk	10
Silica, ground and sifted	25
	100

ART. 23. The bitumen shall come as much as possible from the washings of bituminous sandstone or the asphaltic rock of Maestu, and in their default, from the dry pitch of Trinidad, perfectly purified. It ought to be viscid at the ordinary temperature; never brittle or liquid; drawn into threads it should lengthen and only break in very fine points.

ART. 24. The rock employed should be calcareous, soft, with fine grain, texture fairly compact, regularly impregnated with bitumen so as not to show black and white spots; it should be of a brown color; heated to 122 to 140° F. it should soften and break on being torn. Care must be taken for the areas in asphalte to choose only such pieces as are of the most even grain and richest impregnation. The rock of Lobsan, however, should not be employed alone in the asphalte roadways it ought to be mixed with other rocks less fat in proportions, which will be determined by the Engineers according to the composition of the other rocks. It should contain at least 7 per cent of bitumen, and at the most, 93 per cent. of lime; its change into mastic, must not require more than 9 per cent of bitumen.

ART. 25. The materials entering into the composition of the pavements are the mastics

described in Art. 22, pure gravel grit and natural bitumen to assist the melting. These materials ought to be generally employed in the following proportions, by weight:

Foot pavements with a base of asphalte,	Asphaltic mastic	100
	Bitumen	6
	Grit	60
Foot pavements with a base of slate	Asphaltic mastic	100
	Bitumen	7
	Gravel	50

ART. 26. One month before the award of this contract the competitors must deposit at the office of the works in Paris, samples of—1st, A block of the mastic described above; 2d, Specimens of the asphaltic rocks and the natural bitumens they intend to use; 3d, A note indicating the elements of the composition of the mastics and proportions of the various rocks that they intend to employ in the composition of the asphaltic areas.

The blocks and specimens of rocks and bitumen to have the trade-marks of the works from whence they came and the signatures of the competitors.

The neccessary certificate to compete for the contract will not be delivered till after the examination and acceptance by the Engineers of the specimens deposited. During all the term of this contract the contractor can only use materials exactly similar to the specimens deposited.

ART. 27. Provides for continuous inspection of the contractor's works or the right to compel the contractor to manufacture the mastic in the depots belonging to the City.

ART. 31. The lime employed is to be hydraulic lime in powder. It must be brought onto the works in sealed bags, marked with the name of the maker Only the lime and cement designated in the specifications for the construction and repair of sewers will be allowed.

ART. 32. The broken flint must pass through a ring of $2\frac{1}{2}$ inches and be at least $\frac{3}{4}$ inch thick. It must be free from earthy matters and washed clean.

ART. 33. The sand shall be dredged from the Seine and well cleansed from all foreign matter; it shall be screened from all grains larger than $\frac{3}{4}$ inch for the mortars, or $\frac{1}{16}$ inch for grit for the mastic pavements, the grit for this last purpose shall be perfectly washed and dried before use.

ART. 34. The mortar of hydraulic lime shall be composed of 5 parts of sand and 2 parts of lime, by volume, furnished in powder; the mixture shall be directly reduced to a paste by adding the quantity of water exactly required to reduce it to the consistency of plastic clay.

The cement mortar shall be composed of one part of hydraulic cement of Bourgogne or Portland cement of Boulogne and 3 parts of sand; the sand and cement shall be thoroughly mixed before the addition of any water. All mortar which shall have set shall be rejected.

ART. 35. The beton shall be composed, ordinarily, of two parts in volume of mortar and three of stone. The mixture, made either by the rake or cylinder, must be perfectly uniform.

All beton not used at the time of making shall be rejected.

ART. 36. The bed of beton for the foundation of the sidewalks shall be well rammed and compressed, and must at least commence to set and dry before receiving mastic or asphalte. The beton shall, in addition, be covered with a layer of mortar $\frac{3}{4}$ inch thick.

The gravel for foundation shall pass in every direction through a ring 2 inches in diameter. It must be perfectly compressed and sprinkled with lime grout. This foundation shall have commenced to set before the application of the mastic, and shall be covered with a layer of mortar like the beton.

ART. 39. The ground upon which the mastic pavement is to be placed shall always be previously rammed, watered, and crowned with care. When it is thus made solid the contractor shall spread over it the foundation layer, formed according to the orders of the Engineer, either a bed of beton or of sand covered by a layer of mortar, or a bed of sand impregnated with goudron $2\frac{1}{2}$ inches thick, or any other foundation prescribed by the Engineer.

In all cases the pavement shall not be laid till the foundation has attained the firmness desired, and become quite dry.

The contractor must conform to the following orders for the manufacture of the mastic to be used for pavements.

The mastic shall be prepared and cast in one or more manufactories belonging to the contractor, and which shall always remain open to the inspection of the Engineers and their agents.

The contractor shall, besides, establish in the manufacturing depots, both of asphalte and mastic, offices exclusively for the agents of the administration set apart for the inspection of

the composition of these materials. These materials shall not be admitted into the works without a carter's delivery note given by the inspector, setting forth that they have been manufactured in accordance with the specifications.

There shall only be allowed in the works blocks of mastic conforming to the samples deposited and accepted before the award and bearing their trade-mark, or the old mastics from the walks and streets of Paris. All other bituminous matters, resinous or fatty, found in the works by the agents of the administration will subject the contractor to a deduction of $100 for each time.

To assure the execution of these conditions the contractor must not have in any manufactory, under the same penalty, any other blocks than those which should be prepared in his works, and the old mastics taken up.

The use of the old mastic is authorized in the works of the city in the proportion of one-half with the new. The pieces of the old sidewalks having been perfectly cleaned with great care, and regenerated by the addition of new purified bitumen and a sufficient quantity of powdered asphalte to render the old mastic, when melted, of the aspect and consistence of the blocks in fusion.

This mastic shall be melted in hermetically closed boilers, on wheels of a model approved by the administration, and arranged so that the material can be conveyed from the factory to the place to be used, ready to be employed.

For melting, the mastic is broken into pieces 4 inches cube, then the bitumen is melted and the mastic added little by little.

The grit must not be thrown into the boiler till the mastic is completely dissolved.

During the whole time of the operation the matter must be stirred up almost constantly, so that the combination shall be well made and the mastic not burned.

The mastic being well melted and perfectly homogeneous, it shall be run out in bands of about 5 feet wide, spread with a wooden float, and leveled with a strike, so as to present neither fissure or joint. The mastic must be perfectly level, and match exactly with the curbs, &c., against which it is laid. For this purpose, the parts of the curbs, flags, &c., which will be in contact with the bitumen, shall be previously warmed and goudroned.

ART. 40. Upon the soil, well shaped and rammed, shall be placed a bed of concrete, covered with a layer of mortar.

The asphaltic rock, conforming to Article 24, broken down or decrepitated by heat, shall be raised to a uniform temperature of from 248° to 266° F. and carried to the place of employment in vehicles that will prevent as much as possible the loss of heat. It must be completely freed from the water it contains. The use of old compressed, taken from old roads, is authorized for mixture with new asphalte, in the proportion of one quarter of old compressed to three quarters of new rock, provided that the old shall be cleansed with great care before grinding and mixing with the new.

Asphalte shall not be put on the concrete foundation until it is perfectly set and dry.

The powder shall be spread with a thickness about two-fifths more than the finished thickness, leveled with great care, shall be rammed at first carefully, then gradually augmenting the force by means of cast-iron pilons, heated to the proper temperature in portable furnaces. In specially exceptional cases, the compression may also, with the written permission of the engineer be accomplished by means of rollers.

In every case, after the pilonnage is finished, the surface shall be smoothed by means of a heated iron (lissoir).

The road shall not be opened to traffic until it is quite cool.

ART. 41. The specifications referring to the construction of roads and footpaths are applicable to the maintenance of the same. The contractor will be entitled to the old material and will make the the repairs in new material or in the mixture specified in Articles 39 and 40.

ART. 43. In conformity with the contract price, stipulated hereafter, diminished by the rebate of the awarded contract, the contractor must make the necessary repairs to all asphaltic mastic footpaths and areas, furnishing the necessary labor and materials, so that they shall be kept in a proper state. He must each year of the duration of the contract completely relay, in new material, at least the fifteenth part of the surfaces of mastic and compressed asphalte. The surfaces in mastic must be properly plane and regular, presenting neither hollows nor projections of more than three-eighths of an inch in a circle whose radius is 3¼ feet These surfaces must be free from fissures.

ART. 45. As the works in asphalte or mastic are received by the Engineers they will pass into the charge of the contractor who will receive for the maintenance the price stipulated,

commencing from the 1st of January next following their acceptance, whatever may be the date of said acceptance.

ART. 46. The contract prices dimined by the rebate of the award are applicable to the entire surfrce occupied by footpaths or compressed asphalte, whatever may be their condition.

In the nine last months of the year instalments may be paid on the contract when the Engineers recognize that the conditions have been loyally carried out. The accumulated sums of the these installments must not exceed four-fifths of the amount of the sums which shall be due after the time has expired. The balance of the contract price of the year will be paid in the course of the first quarter of the following year.

ART. 47. The repairs over trenches for sewers, water and gas pipes or other works will be paid for once at the schedule price, but no demand for further payments on account of sinkings or other dilapidations will be entertained, and the surfaces on these trenches must be kept in the same good condition as the others. For the purpose of securing settlement the contractor may keep the trenches repaired with flint (Macadam), not longer than 15 days.

ART. 49. All damages in the bituminous surface, such as fissues or cracks of at least $\frac{1}{8}$ inch in width, or parting from the curbs $\frac{1}{16}$ inch in width, any lifting up or breaking away of the mastic for at least $\frac{3}{4}$ in depth, depression in consequence of settlement of $\frac{3}{4}$ inch at least in depth under the straight edge, 3¼ feet long, will subject the contractor to a deduction of 3 francs (58 cents) per day, when the repairs shall not have been done within 48 hours after notice given by the Engineer.

ART. 51. During the continuance of frost, and during the first month after the commencement of the thaw, there shall be no repairs to the pavements maintained by the contractor, and the inspection for defects shall be suspended, but the contractor shall fill with sand and gravel any holes in these pavements within 24 hours after notification by the Engineer, under a penalty of 10 francs ($1.93) for each day they remain unfilled. He may also be authorized, in exceptional cases, to fill the holes with broken flint or melted bitumen, but must replace the flint or bitumen with asphalte as soon as the weather permits. It must be so arranged that the main repairs, intended to re-establish the normal outline of the road ways, are effected from May 1st to November 1st.

ART. 57. The contractor shall execute in private houses the junctions rendered necessary by changes in the public way, which will be paid for according to the price of his contract, subject to the rebate when the works are executed on account of the City.

ART. 65. When a workman leaves one of the districts of the works under the Municipal service, he must have a certificate from the contractor showing the cause for which he left.

This certificate shall be submitted at once to the Engineer who shall be at liberty to refuse the right of employing the said workman, without the contractor deriving therefrom any excuse for not furnishing, when requisite, the number of workmen required. In default of a certificate the workman cannot be admitted, except on the written order of the Engineer.

NOTE.—There are 75 articles in this contract, those not given referring to the setting of curbs, &c., transport of materials and the relations between the Engineer and contractor.

SCHEDULE OF THE PRICES FOR THE WORK SPECIFIED ABOVE.

NOTE.—All the prices below comprise the incidental expenses and the profits of the contractor, and are subject to the rebate of the award.

(This contract is let in 3 lots, the rebates are 7 %, 20.2 %, and 14 %, respectively).

DAY WORK.—The day of a workman, cart or machine, shall be 10 hours of effective work in all seasons; fractions more or less shall be counted by the hour, or $\frac{1}{10}$ of the day.

The night hours shall be paid half as much more as those of the day, excepting watchmen. Night hours will be counted only from 7 P. M. to 5 A. M., in summer, and from 5 P. M. to 7 A. M. in winter. The summer period begins March 1st, and winter November 1st.

1.	A day of	a laborer	.96¼
2.	"	an ordinary mason	1.06
3.	"	an asphalte helper, or of a mason's or paver's helper	.87
4.	"	Granite cutter	1.35
5.	"	Sandstone cutters, pavers and Asphalte workers	1.26½
6	"	watchman	.53

7. Night watchman ..... .79
8. Day of one-horse wagon and driver 2.70
9. " two-horse " " 4.05
21. 1 cubic yard of stone broken for concrete 1.22
22. " ground hydraulic cement 5.13
23. " river sand 1.18
24. " pit sand ..... .89
25. " river sand, washed and dried for mastic 1.48
27. 100 pounds of Roman cement ..... .58
28. " Portland cement ..... .67
29. " asphaltic rock ..... .68
30. " mineral goudron, from Lobsan, Bastennes, or other recognized as equivalent to them, and purified Trinidad or Maestu 3.24
49. 1 cubic yard of mortar, composed of 2 parts of ground hydraulic lime and 5 parts of sand 3.10
50. 1 cubic yard of mortar, composed of 1 part of hydraulic cement of Bourgogne, and 3 parts of sand 5.02
51. 1 cubic yard of mortar, composed of 1 part of Portland cement and 3 parts of sand. 6.42
52. 1 cubic yard of concrete, composed of 3 parts of broken stone and 2 parts of mortar (No. 49) 3.03
53. 1 cubic yard of concrete, composed of 3 parts of stone and 2 parts of mortar (No. 50). 3.99
54. " the same, with mortar No. 51 ..... 4.65
55. 100 pounds of natural bituminous mastic in blocks, made from rock of Seyssel, or other equivalent, ready to be employed 1.02
60. 100 pounds of compressed asphalte, taken from streets to be repaired, shall be taken by the contractor (without rebate) at ..... .35
61. 1 square yard of old sidewalks in mastic shall be taken by the contractor, without regard to its thickness, and without rebate, at ..... .19
70. Taking up 1 square yard of compressed asphalte, piling the material included .. .014
71. Taking up 1 square yard of mastic sidewalk, with piling the material ..... .003
73. Cleaning and leveling an old Macadam road to secure a surface of mortar for compressed Asphalte, per square yard ..... .10
93. 1 square yard of new natural asphaltic mastic, 0.6 inch thick ..... .53
94. Greater or less value of each $\frac{1}{10}$ of an inch in thickness ..... .045
95. 1 square yard of sidewalk relaid in natural asphaltic mastic, 0.6 inch thick, the old material belonging to contractor ..... .40
96. Greater or less value of each, $\frac{1}{10}$ inch in thickness ..... .025
97. 1 square yard of pavement, 0.6 inch thick, composed of one-half new and one-half old mastic ..... .50
98. 1 square yard of repairs of pavements composed as above ..... .32
99. For each $\frac{1}{10}$ inch in thickness, more or less ..... .02
102. 1 square yard of compressed asphalte 1.6 inches thick, comprising regulating the surface of the ground, but neither excavation, embankment, nor foundation of concrete 1.73
103. For each $\frac{1}{10}$ in thickness, more or less ..... .17
105. 1 square yard repairs of road 1.6 inches thick, the contractor retaining the old material 1.04
106. For each $\frac{1}{10}$ in thickness, more or less ..... .17
108. 1 square yard of foundation for pavement in asphalte or mastic, comprising regulating and ramming the road-bed, but not excavation.
109. 1 square yard concrete of hydraulic cement rammed to 4 inches in thickness, comprising a covering of mortar No. 49 at least $\frac{1}{10}$ inch thick ..... .34
110. 1 square yard concrete of cement No. 53, rammed to 4 inches thick, comprising a covering of mortar No. 50 ..... .46
111. 1 square yard concrete of cement No. 54, rammed 4 inches thick, covered with mortar No. 51 ..... .54
12. 1 square yard on natural soil, with a bed of sand 0.8 inch thick ..... .04
17. Repairs in which all or a part of the old materials are used, will be paid for at three-quarters of the prices above mentioned.

207. 1 square yard of sidewalk, in natural mastic, half an inch thick, comprising a hydraulic lime concrete foundation, 4 inches thick after ramming, with regulating but not excavating..... .93

208. Note. When the foundation is in cement concrete the price above will be increased by the respective differences between each of the prices of Nos. 110 and 111 and that of 109.

209. 1 square yard of mastic like 207, on the natural ground, covered with a bed of sand 0.8 inch thick..... .63

210. 1 square yard of mastic like 207, on the natural ground, covered with hydraulic mortar..... .68

211. Note. When the pavement is one-half new mastic with old material, the prices above will be diminished by..... .09

212. 1 square yard of compressed asphalte 1.6 inches thick, including a foundation of hydraulic lime concrete, rammed 4 inches thick, including dressing and ramming the soil but not excavation..... 2.07

213. 1 square yard of compressed, with concrete of cement No. 51..... 2.21

Additional price for work executed on embankments more than 1 yard high, or on trenches, whatever may be the thickness of the pavement or concrete.

215. 1 square yard of mastic..... .22

216. " " compressed..... .36

217. Maintenance of 1 square yard of sidewalk in asphaltic mastic, in conformity with these specifications, per annum..... .05

218. The same for roads in compressed asphalte..... .19

219. Additional price for maintaining cross walks of compressed asphalte on Macadamized roads, and of gutters bordering them..... .10

248. For works not mentioned in the present schedule, the prices in the schedules now in force for maintenance of public ways or sewers and water service will be paid: which prices will be subject to the rebate of the present letting.

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